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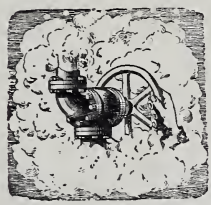

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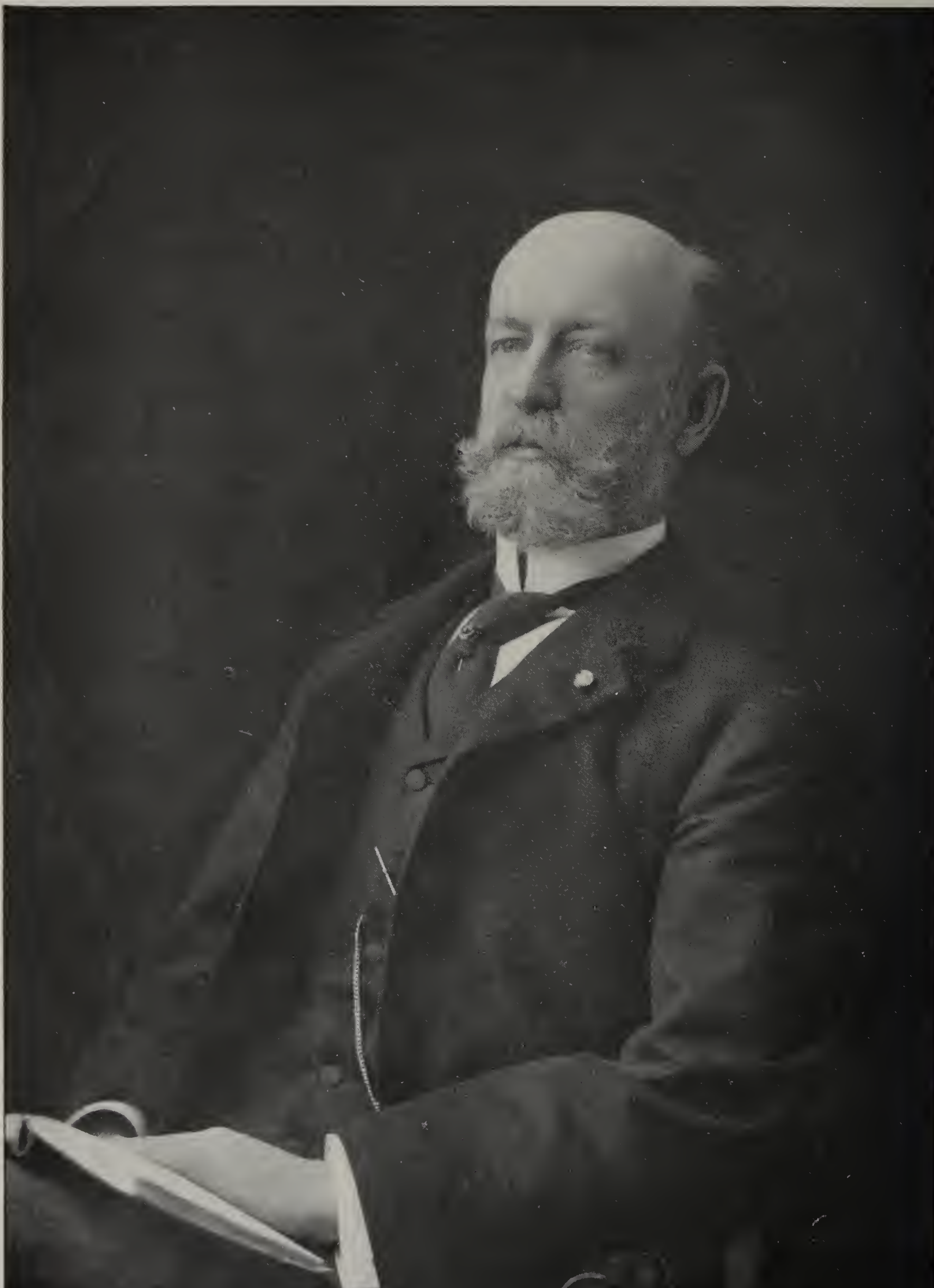


B. H. WARREN

THE NEW PRESIDENT OF THE ALLIS-CHALMERS COMPANY CHICAGO

CASSIER'S MAGAZINE

VOL. XXVI MAY, 1904 No. 1

SOME MODERN QUAYSIDE CARGO APPLIANCES

By Brysson Cunningham, B. E., Assoc. M. Inst. C. E.

IN an article on the subject of docks, printed in CASSIER'S MAGAZINE for April, 1904, the writer emphasised the importance of rapidity and despatch in all manœuvres connected with the berthing and departure of ships. Equal stress must be laid upon the necessity for celerity in the operations of handling the cargoes between ship and shore, for it is evident that any delay in this respect will go far to discount, if not to neutralise altogether, the advantages to be gained from compliance with the former injunction. It would be difficult to overrate the value which the element of time has acquired in modern undertakings, and especially in regard to shipping enterprise. Under present conditions of trade, it is the predominant factor, and its economisation is superior to all other considerations.

Take, for instance, the case of the large steamships which cross the Atlantic. Consider the vast array of hands, aship and ashore, employed in connection with one of them; the enormous weekly pay-sheets; the establishment charges; the interest on capital; the depreciation of property; the cost of maintenance; and from these form some idea of the money which would be expended without return by the missing of a tide,—the mere detention of a ship for an extra hour or two in port. Multiply this loss by the number of voyages in a year, and the sum will reach an almost incredible total. It has, in fact, been authoritatively stated that in the case of one Atlantic liner alone the loss of a single day per voyage is equivalent to £2400 per annum.

Delay may arise from other sources than those connected with the actual shipment and discharge of cargoes; but in this article the writer will confine his attention to this particular aspect of the subject, and consider the ways and means best adapted to the rapid handling of goods at the quayside. The many varieties of merchandise to be handled demand, in many instances, special methods of treatment. Such is the case with coal, grain, ore, oil and timber, to mention only a few examples. It is proposed to briefly review these systems in turn; but before proceeding with this, preliminary attention should be given to those appliances which are used in connection with the greater and

TRANSPORTERS AT THE WOOLWICH ARSENAL, BUILT BY THE TEMPERLEY TRANSPORTER CO., LONDON. A SECTIONAL VIEW OF THE STORES AND AN ELEVATION OF ONE OF THE TRANSPORTERS IS GIVEN ON PAGE 7

more miscellaneous mass of goods denominated general cargo. The term is a most comprehensive one; it covers such wide contrasts as bales of cotton, pigs of lead, sacks of flour, tierces of lard, cases of machinery, boxes of bacon, bundles of staves, hogsheads of tobacco, and so on.

A modern cargo steamer will carry from 3000 to 5000 tons of such material, comprising, perhaps, 30,000 to 40,000 separate packages, in addition to bulk grain, fresh meat and live stock, making from 10,000 to 12,000 tons deadweight, and occupying upwards of 600,000 to 700,000 cubic feet of space. The rate of discharge will sometimes reach 300 tons per hour, and the rate of loading 250 tons per hour. This is a recent record of the *Cymric*, one of the most modern of the White Star liners. Another ship, the *Georgic*, has discharged a full cargo of 10,246 tons weight and 716,000 cubic feet bulk and loaded 2409 tons in a period of sixty working hours. Liverpool was the locale in the forego-

ing cases. The record for London appears to be held by the steamship *Milwaukee*, which has discharged a cargo of 11,000 tons deadweight in sixty-six working hours.

When the conditions under which this class of work is carried on are considered, such performances indicate a very high standard of management and efficiency. The very dissimilarity of the material dealt with renders its manipulation the more difficult. It is not possible to utilise special appliances; such means as are available must be readily adaptable to widely different conditions of load and working. Furthermore, the problem is complicated by climatic conditions. Few goods are altogether exempt from atmospheric influences, and in the majority of instances some protection must be afforded from the vicissitudes of the weather. Hence it is that one of the most essential features of a quayside is a transit shed for the reception of discharged goods, as well as of those awaiting shipment. And here it cannot fail to have struck the most casual observer that there is considerable diversity of practice in regard to the location of such sheds. At Liverpool, for example, they are placed in close proximity to the edge of the quay, leaving only a narrow margin of less than 10 feet entirely devoid of railway sidings. At other ports, Hamburg, for instance, there is a much wider margin in front of the sheds, accommodating two and even three lines of rails and extending in some cases to as much as 50 feet in width.

Such dissimilar dispositions are due to several causes. In the first place, a port may or may not constitute the ultimate destination of a ship's cargo. In the second place, the cargo may be fairly uniform in character, or it may be very diverse. Thirdly, it may be consigned mainly to one individual or firm, while, on the other hand, the consignees may be very numerous.

Now, if we have a heterogeneous mass of goods consigned to a large number of people, all resident locally or at no great distance, obviously the most judicious arrangement is to deposit the goods upon the quay where they can be duly assorted and despatched by cart or lorry to their respective destinations. When, on the contrary, the cargo is largely of one kind, consigned to but

ELECTRIC QUAY CRANES AT HAMBURG

ANOTHER VIEW OF THE TEMPERLEY TRANSPORTERS AT THE WOOLWICH ARSENAL DOCKS

few individuals, and they resident at some considerable distance inland, the preferable course is to discharge direct from ship to rail, so as to avoid any unnecessary intermediate handling.

Whichever of these systems be in vogue, and sometimes both are to be found at the same port, there will be a corresponding arrangement of plant to meet local requirements. The appliances thus utilised comprise cranes, jiggers, winches, and transporters.

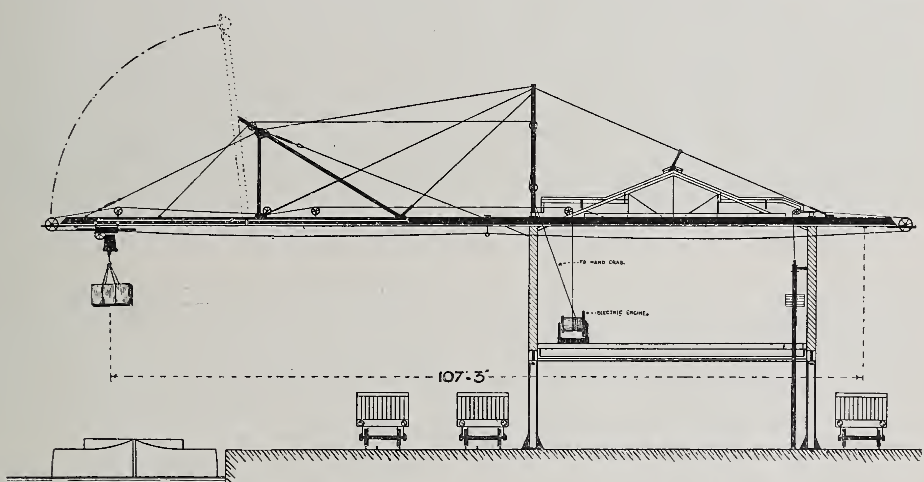
Cranes claim first attention, from their numerical preponderance and more general application. Crane types are varied,—too varied for anything like an exhaustive summary in a magazine article, even though the classes be limited to quay work; but there are certain prominent features common to all, of which some notice must be taken.

The selection of a crane naturally depends to a very large extent upon the space at disposal for operating it, and, in this way, the disposition of the quay-shed exercises primary influence in determining the type of crane available. For sheds close to the quayside, roof cranes and wall cranes are inevitable: in other cases they are permissible; but the more general rule is to provide cranes movable over tracks at the quay level.

To avoid the monopolisation of the quay frontage, these cranes may be furnished with pedestal bases, admitting of loaded waggons passing beneath them, and in certain instances of moderately narrow quays, as also of some wide ones, these cranes are of the platform type, having the front support running along a rail at the quay edge and the back support carried by a corbel course on the shed structure at the level of an upper floor or the eaves. This is a common feature at foreign ports, notably at Bremen, Emden, and Hamburg.

Quay cranes are of all capacities, from 10 cwts. to 150 tons; but those dealing with ordinary cargo do not generally exceed 5 tons, and the usual power is from 30 to 40 cwts. Such cranes are quite capable of transmitting goods through a ship's hatchway in quantities as large as can be conveniently handled by stevedores or wharfingers. When heavy packages have to be dealt with, the lifting power of two cranes may be combined, or the load may be handled by the interposition of a snatch block and tackle.

If the motive power employed for working the crane be hydraulic, it becomes a matter of prime importance to limit the capacity of the crane to the usual working load, because when the



CROSS SECTION OF STORES AT THE ROYAL ARSENAL AT WOOLWICH SHOWING A TEMPERLEY TRANSPORTER FOR THE RAPID STORING AND SHIPPING OF WAR MATERIAL

A CARGO STEAMER UNLOADING AT A MANCHESTER DOCK

crane is not working at full load there is waste of energy. This drawback does not apply to electric cranes, the supply of power to which can be regulated to suit the load; but, in any case, there can be no advantage in having lifting capacity much in excess of normal requirements.

The action of a quay or shed crane is intermittent and irregular. The period of actual lift constitutes but a small part of the cycle of operations. There are frequent startings and stoppages. Moreover, the load is not uniform, and the rate of lifting is variable. Thus, in discharging from a ship's hold, when the hook has been attached, the first thing is to drag the charge towards the centre of the hatchway, in order that it may be clear of stanchions and coamings. This is done comparatively slowly. Then lifting commences and should proceed as rapidly as possible consistent with steadiness of motion. Near the top of the lift speed is slackened more or less rapidly, until motion ceases altogether, and the load is held by brake or otherwise, while it is slewed through the requisite angle; then it is lowered and deposited. In competent hands slewing may commence as soon as the load is clear of deck obstructions, but the dual action increases the risk of surging. The conditions of working may accordingly be summed up in three phases:—1, rapid acceleration; 2, uniform motion; and 3, quick stoppage.

Actual time consumption obviously depends on the height of lift and the range of slew; but if the former be taken at from 40 to 50 feet and the latter at about 180 degrees, the complete cycle of operations (lifting, slewing, depositing, and returning) should not occupy a longer period than one minute, and in many cases it can be accomplished in forty-five seconds or even less. A good average, under favourable conditions, would be 70 cycles per hour; but spread over any lengthy period this rate could hardly be maintained, for reasons entirely unconnected with the crane. To fulfil ordinary requirements, the lifting speed will range, at full load, from 150 to 200 feet per minute, and unloaded it will be 50 per cent. more. The lower-

TRANSIT SHEDS AT MANCHESTER DOCKS

ing speed, at full load, will be about 300 feet per minute, and unloaded half that amount. Slewing will probably take five or six seconds. Many cranes, however, work faster than this.

The essential movements of a crane are, as already referred to, lifting, lowering, and slewing. To these may be added, in certain cases, derricking or luffing, *i. e.*, alteration of the rake of the jib. This feature is more characteristic of British than of foreign cranes. For movable cranes some means of propulsion is, of course, desirable. This, however, may in the generality of cases be achieved satisfactorily by hand, since when once a crane has been adjusted to command a particular hatchway, there is little necessity for it to leave that position until the conclusion of operations.

The power most suitable for application to quay and shed cranes has been the subject of much controversy. Steam, hydraulic power, and electricity are all employed. The first named, however, is scarcely a serious competitor, being adopted only for isolated cases in which locomotion is an essential feature. Where an extensive installation is concerned, the other two systems are alone practicable. Each of these has warm supporters. The principal advantages of hydraulic power are simplicity, precision, and less risk of accident, whilst the chief points in favour of electricity are convenience and adaptability, to which may be added in many instances superior economy. The question, however, is rather too complex for generalities.

For electric cranes the continuous current, say between 200 and 500 volts, is most serviceable. It is superior to the alternating current in overcoming the inertia of loads at starting. Moreover, the continuous current is more easily regulated, and it can be stored in batteries to meet variations in load. Of the various forms of motor the series-wound, coupled permanently to the gearing, conforms best to the conditions of varying load; but shunt-wound motors, with clutch connections, are preferable for continuous running. Cranes are fitted with either one or two motors; in the latter case, which is, perhaps the

A THREE-TON ELECTRIC JIB CRANE ON A PEDESTAL BASE ADMITTING OF WAGGONS PASSING UNDERNEATH. BUILT FOR THE CLYDE NAVIGATION TRUSTEES BY MESSRS. STOTHERT & PITT, LTD., BATH, ENGLAND.

more common arrangement, one motor is utilised for lifting and the other for slewing.

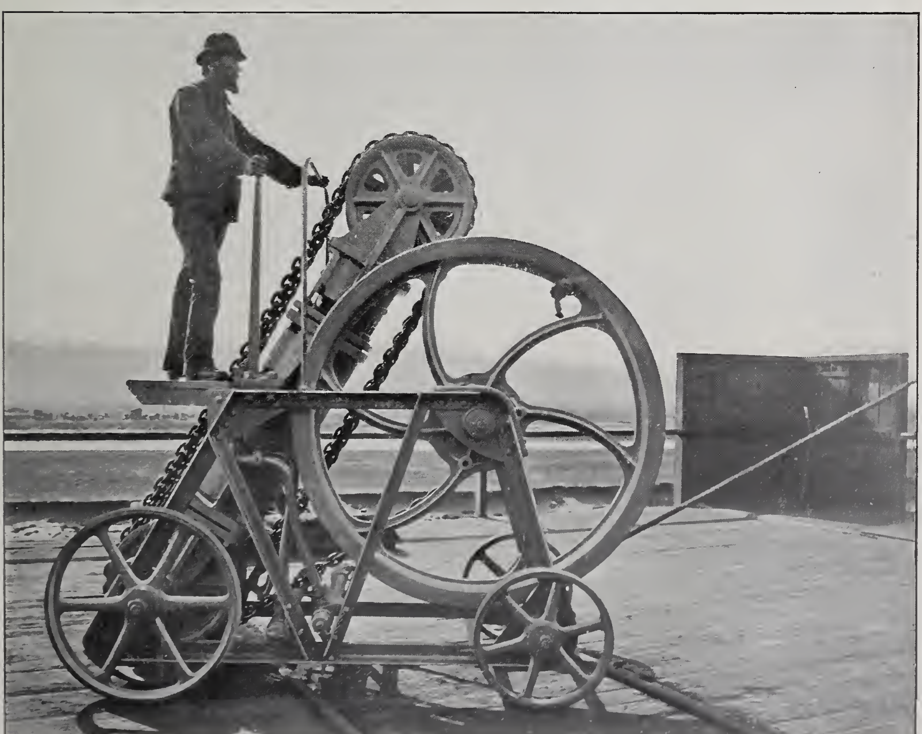
In cranes where the lifting barrel is always in gear, lowering has to be effected by switching out or reversing the motor, and care must be taken to check the lifting speed in time to prevent the hook from reaching and overriding the jib pulley under the momentum of the revolving armature, the result of which would probably be the bending of the tie-rods attached to the jib head. Stoppage is effected by an electric brake working on the armature shaft, but the exercise of due precaution prevents the utilisation of the lifting motor at full speed towards the close of the lift.

On the other hand, with a lifting barrel in temporary connection with the motor through the medium of a friction clutch, full speed may be maintained

almost to the top, at which point the barrel is disconnected. The inertia of the barrel and its brake-drum is comparatively insignificant, and they come to rest practically instantaneously. Lowering is done without perceptible delay, under the control of a foot-brake, and it may be completed even before the lifting armature has ceased to revolve.

For hydraulic power, the ram with sheaves and multiplying gear is most generally adopted. The action is steadier, more direct and safer than that of rotary machines, and in addition to this the apparatus is less liable to get out of order, and it can be more conveniently housed. The service pressure ranges between 700 and 1200 pounds per square inch. Lifting is performed by a single ram or piston with differential faces; and slewing, by twin rams with a single chain passing round and attached, at its centre, to a turning drum on the pivot.

The hydraulically worked roof crane at Liverpool, shown on page 14, is to the design of Mr. A. G. Lyster, the engineer at that port, who inaugurated this type about 1884. Its utility is abundantly demonstrated by the fact that no less than 120 of these cranes are now in use. The crane is capable of raising its maximum load of 30 cwt. at a speed of 200 feet per minute and of lowering the unloaded hook at 160 feet per minute. It can be luffed so as to reduce its outreach by 18 feet in nine or ten seconds. There are four cylinders, one for lifting, one for luffing, and two for slewing. The two former are set parallel to the pitch of the roof, and have rams of 10¾ and 8¾ inches diameter, with strokes of 12 feet and 4 feet, respectively. The slewing rams are also 8¾ inches in diameter and are placed horizontally. As an instance of the practical capabilities of a crane of this type, the fact may be mentioned that one of them recently discharged 1700 casks, each weighing 5 cwts., from the steamship *Canadian*, so



AN HYDRAULIC JIGGER MADE BY SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD., NEWCASTLE-ON-TYNE

A WALL CRANE AT LIVERPOOL DOCK SHEDS. MADE BY THE LEEDS ENGINEERING & HYDRAULIC COMPANY, LEEDS, ENGLAND

that the whole operation of landing, weighing and stowing ready for cartage was performed in four and three-quarter hours. It has also discharged large boxes of bacon at the rate of 120 per hour. The maximum lift is 76 feet.

The wall crane, shown in the illustration on this page, deals with loads up to 20 cwts, and its lifting and lowering speeds, fully loaded, lie between 6 and 7 feet per second. It has an outreach of 12 feet and a clear lift of 32 feet. It is capable of lifting through 10 feet, turning through 120 degrees and lowering through 5 feet,—all in seven to eight seconds. The rams are 9½ inches in diameter, with 3 feet 2½ inches stroke. The erectors were the Leeds Engineering & Hydraulic Company. In both the above cases the hydraulic pressure is 750 pounds per square inch.

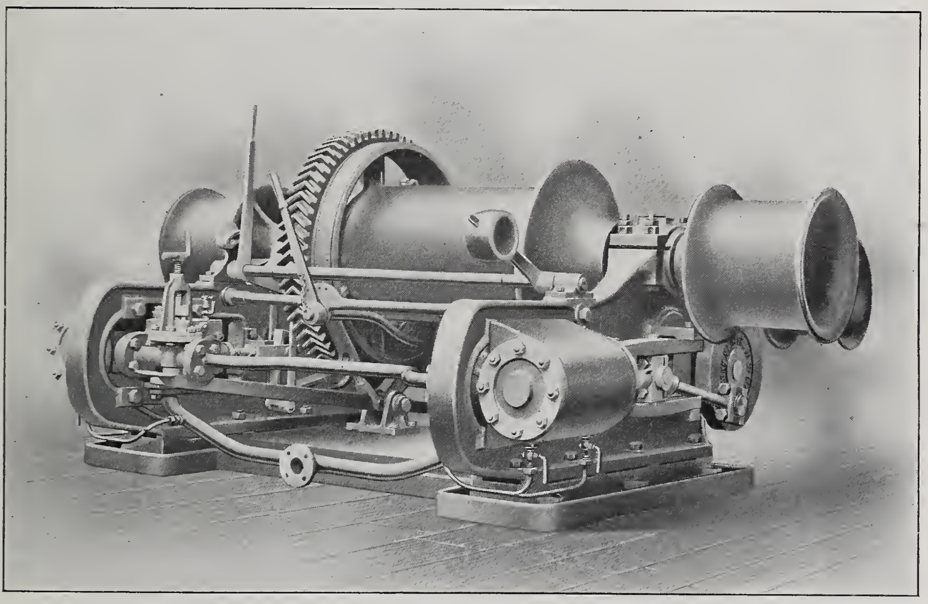
On page 10 is shown a good example of electric crane built by Messrs. Stothert & Pitt, Ltd., of Bath, for the Clyde Navigation Trustees, under the supervision of Mr. G. H. Baxter. This crane is capable of lifting loads up to 5 tons weight, through a total height of 80 feet, at a radius of 41 feet. The lifting speed at full load is 150 feet per minute, and the slewing speed at the jib head, 300 feet per minute. The crane has a square wheel base, travelling upon a track of 14 feet gauge. The superstructure revolves upon a ring of twenty-four cast-steel live rollers, contained between two cast-steel roller paths. The load is carried by a steel wire rope coiled on a spirally grooved drum, which is connected with the driving shaft by means of a friction clutch. A large friction-brake drum is keyed to the lift-

ing barrel, and is so interlocked with the controller that the motor cannot be started while the brake is on.

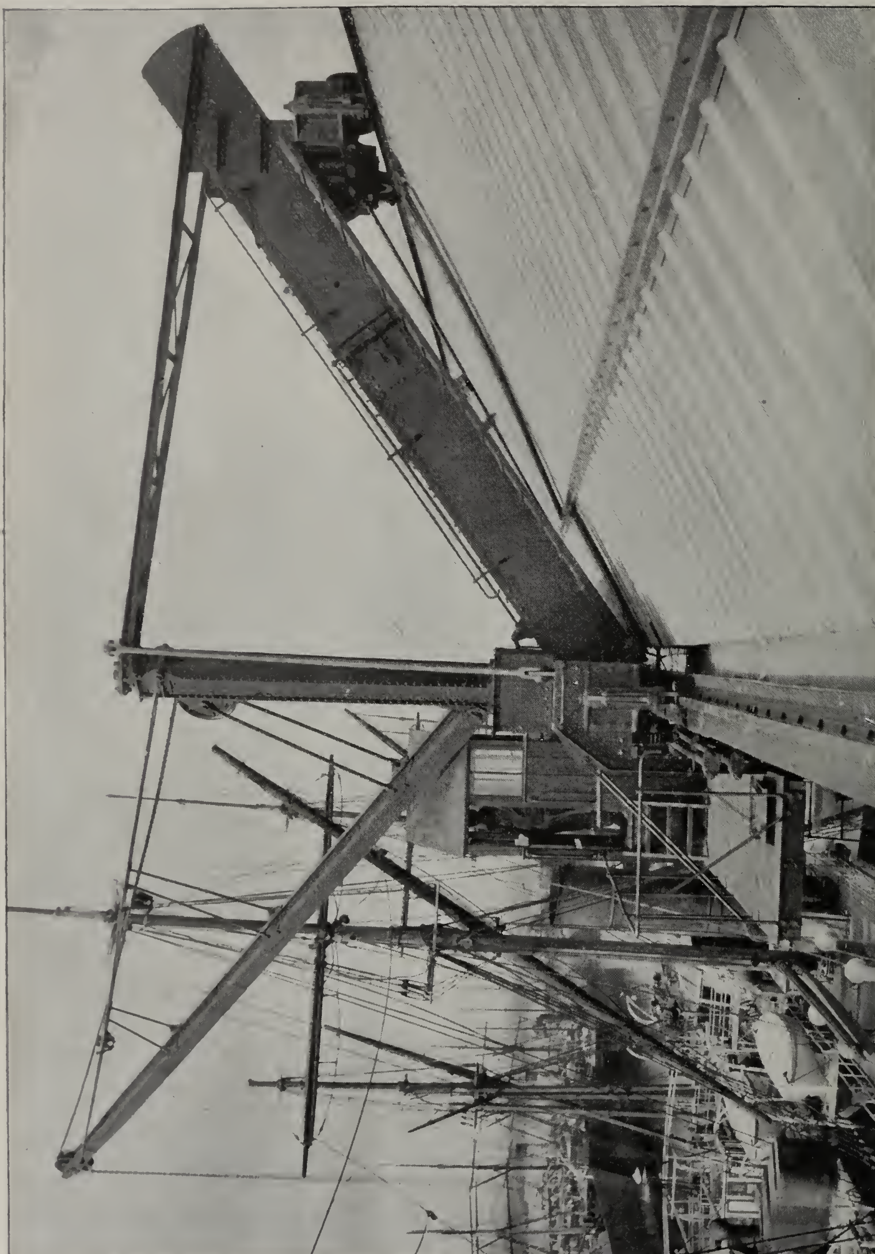
The Hamburg cranes, shown on page 5, were constructed for that port by the Benrather Maschinenfabrik of Benrath, Germany, and London, and have a lifting capacity of three tons at a radius of 35 feet, the maximum lift being 85 feet. The crane proper is mounted on a platform affording a clear headroom of 16 feet upon the quay. The difference in level between the track rails of the inner and outer supports of the platform is 18 feet, and their horizontal distance apart is 45 feet. The jib head pulley is 45 feet above the quay level.

A very common practice nowadays on board cargo steamers is that of raising goods to the deck level by means of the ship's winches, whips from which run to gin-blocks suspended over the hatchways. The packages are then either trucked ashore, or else slid down inclined gangways when the ship's deck is sufficiently above the quay level for the purpose. Ships are also fitted with revolving deck cranes, as well as with derrick poles attached to the feet of the masts, and these, too, play an important part in the manipulation of cargoes. The motive power is generally steam from the ship's boilers; but, in some modern instances, hydraulic installations have been effected, the pressure being obtained by air vessels instead of weighted accumulators.

Hydraulic winches are to be found as part of the quay equipment at some ports; but the rotary action, for want of a suitable motor to work under high pressure, has not proved so satisfactory as the rectilinear motion of the jigger. The latter is of two varieties. The hydraulic jigger is generally a direct-acting ram with multiplying gear, the chain of which is attached to the smaller barrel of a differential wheel or axle. In order to give portability, the apparatus is mounted on a carriage, for which rail tracks are not usually provided. This renders the machine adaptable and convenient in dealing with light loads, say not exceeding 10 cwts., in which case speeds of 600 feet per minute have been recorded. The lifting rope passes over a suspended



A SHIP'S STEAM WINCH, MADE BY MESSRS. J. H. WILSON & CO., LTD., LIVERPOOL



A ROOF CRANE MUST BE USED WHERE THE GOODS SHEDS ARE CLOSE TO THE QUAYSIDE. BUILT BY SIR W. G. ARMSTRONG, WHITWORTH & CO., LTD., NEWCASTLE-ON-TYNE

pulley block, as described in the preceding paragraph.

The hand jigger, used for lowering purposes, is simply a double wheel or drum, fitted with a brake. Of the two ropes with which it is furnished, one is wound up unloaded simultaneously with the lowering of the other under load. As cargo appliances, hand jiggers occupy merely a secondary position; but they are useful for loading off into carts and lorries goods which have previously been deposited on shed upper floors.

Transporters are a modern invention by no means confined to dock work, but offering signal advantages in that connection. The principle is that of an overhead track with a suspended carrier, the movements of the latter being comprised in lifting, travelling, and lowering.

The earlier forms provided motion in one plane only, but later developments have curved tracks. Travelling is either horizontal or inclined. The lifting speed ranges from 200 to 300 feet per minute. Travelling is much more rapid, attaining, in some cases, a rate of 1500 feet per minute.

The Temperley Transporter Company have constructed a very large number of their transporters in connection with shipping operations, and views are given on pages 4, 6 and 7 of an installation at the Royal Arsenal, Woolwich. The loads usually lifted are from 20 to 30 cwts.; the maximum capacity is 2 tons. Each beam is long enough for a total effective travel of 107 feet. The outreach from the face of the building is about 62 feet, of which about 30 feet constitute a hinged arm which can be raised out of the range of the yards and masts of shipping when not in use. The track in this case is a fixed one, but in many other instances the transporters are movable along the quay, being affixed to travelling towers of open framework. Such is the arrangement adopted in connection with an installation at Delagoa Bay, where there are four travelling tower transporters which can be connected up in any desired position, with fixed beam-prolongations passing through the transit sheds. In this way loads can be run direct from a vessel to any point on the wharf, within the shed, or in the roadway beyond. The ordinary working load is 15 cwts., but loads up to 2 tons in weight can be handled. The hoisting speed is 250 feet per minute, and the maximum travelling speed, 650 feet per minute.

In both the foregoing examples the transporter is operated by a series-wound, continuous-current motor, the lifting drum being disconnected for lowering under the control of a foot-brake. In the Delagoa Bay apparatus the same motor, through a worm gear and a second drum, raises the hinged arm at the close of operations.

WASTED MACHINERY ON THE PANAMA CANAL

By George E. Walsh

THE disastrous attempt by the French to build the Panama Canal has furnished picturesque material for exploiting the conditions of one of the most unique portions of the globe. Dividing the two Americas by a canal has been a dream of navigators since the early days when it was definitely discovered that the mythical northwest passage to the Indies did not exist, and that Columbus had merely discovered a new continent and not a shorter route to the wealth of the Orient. Connecting the two halves of a great continent by a strip of land barely twenty-one miles in width, the Isthmus has naturally offered conditions which attracted the attention of engineers and scientists; but with all of its apparent natural advantages for connecting the Atlantic and Pacific, the strip of land that has caused so much international legislation and scheming has proved a veritable hot-bed of trouble and difficulty.

Never before in the world's history was the engineering profession in a better position to take up the work of cutting the Isthmus in two, and this must be considered in studying the work of the past and future. Whether De Lesseps could have accomplished the dream of his life, with his machinery and implements of more than a quarter of a century ago, if fraud had not entered the question, is a matter that has not been definitely answered by the investigators of recent times. In fact, the several commissions appointed by the United States have given little attention to the plant and equipment established by the French company, and yet, to a large extent, detailed information of this character would furnish some reliable data of a most interesting and valuable nature. It is well known that much of the French machinery and extensive working plant are rotting away along the Panama Canal route.

The climate of Panama has always offered almost insurmountable difficulties to engineering undertakings. It is undoubtedly more responsible for early failures in cutting through the canal than many imagine to-day. But the financial troubles of the company and the general mismanagement of its affairs so far overshadowed all other facts that the world was left in ignorance of features that will probably be better appreciated in the near future. The unhealthfulness of the Isthmus may be proverbial in a way, and yet its effects upon the life of iron and steel are not generally known. The old saying that for every sleeper of the Panama Railroad the lives of three Chinamen were sacrificed, has been further modified in recent times by the additional clause that each foot of the canal represents twice this number of lives.

The sanitary conditions in an engineering camp in the tropics of to-day are vastly improved over those which prevailed a quarter of a century ago. The loss of life is thus proportionately less. It is possible to safeguard against disease even on the Isthmus so that the mortality of workmen will be vastly reduced. Nevertheless, the sacrifice of human life must, of necessity, be great before the world's commerce will be able to pass from ocean to ocean through the new canal.

What is commonly spoken of as "the ghost of Panama" by those living on the Isthmus is something that must be

A VIEW ON THE PANAMA CANAL DURING THE EARLY DAYS OF CONSTRUCTION

THE DE LESSEPS RESIDENCE AT COLON

reckoned with, and it is a spectre that paralysed many an earlier engineer's efforts and reduced him to a condition of apathetic carelessness. The heavy mist which rises from the soil when it is disturbed is a breeder of disease against which no man is proof. Undisturbed, the soil is moist and rich, performing marvels of vegetable changes. Plants, vines, trees, and shrubs spring up from it with the quickness of magic. The soil that is opened to-day may, within a few weeks, be literally covered with a rampant growth of long-leaved, dank, heavy plants and vines. Vegetation struggles vigorously for possession of every square foot of ground.

But from the disturbed soil a heavy white mist rises in clouds, obscuring the atmosphere like a sea fog. With the air quiet, this mist hovers over the sea and land, and the sun, struggling to penetrate it, produces a sickly, sticky condition that makes life precarious. When this white ghost of the Isthmus rises, the native retires to his home and waits for it to disappear. He knows that it means death to attempt to work in the sun when the mist is abroad. During the early work on the canal the white men were stricken in large numbers, and the "ghost of the canal" established its reputation as a terrible enemy. The digging along the line of the canal made fever prevalent over a good part of the Isthmus. During the succeeding years the mists have been less in evidence, and sickness has been less apparent.

The French engineers who worked on the canal were soon apprised of the condition of the climate after arriving. Some of them returned immediately to their native country, refusing to remain in such a pest-hole of fevers. A few attempted to stay until they could reap a part of the reward held out temptingly to them. Most of these died within a few months or years, and their deaths served as a lesson to succeeding ones.

There was another class of canal workers who accepted the dangers philosophically. They knew their chance of living was a gamble, and not an even one at that. The odds were heavily against them. Therefore, they proceeded to extract what little comfort they could from their position. Life was made a fast one in many instances, and money intended for building the canal

was used up in riotous living. Boats, tugs, and dredges were converted to private uses, and railway steel was used for the foundations of houses, or employed for buildings that would make life more comfortable for the men. The expenses of the canal company thus mounted up to huge figures without any returns to show for them.

The soil of the Isthmus is soft and silty, and the wooden and steel houses put up by the officers of the French company often settled several feet within the course of a year or two. Expensive machinery was, in some cases, used for the foundations for these houses. It is said that a hundred thousand dollars' worth of machinery has been sunk under some of the houses, which successively formed the homes of half a dozen superintendents of the canal company.

The effect of the moist atmosphere on iron and steel is one of the marvels on the Isthmus. Rust appears on the unprotected metal within a few hours after exposure, and rapidly eats its way in. Scattered all about the canal at Colon and Emperador are huge quantities of machinery so badly corroded that a knife can be thrust into the metal as if it were cheese. Huge anchors, steel rails, and dredging apparatus lie in the soil half buried, which, when unearthed, are as rotten as decaying vegetation. All along the line of the proposed canal machinery is found in a more or less decayed condition. Its waste is a huge monument to the extravagant methods of the early company.

There has been little attempt to carry away or rescue any of this discarded apparatus. Probably $50,000,000 worth of old machinery was thus wasted, which might have been saved through proper care in storage and protection. Several years ago this machinery was piled in huge heaps. It is now over twenty-five years old, and is practically worthless. It is doubtful if it could ever be used again on the work for which it was intended. It is antiquated in design, and too small in size for the required service.

A COMPLETED SECTION OF THE PANAMA CANAL

The equipment included miles of steel

NATIVE HOUSES ON THE ISTHMUS

rails piled up in the open air; thousands of dump cars are likewise collected in different places awaiting the coming of the next canal company. Scores of locomotives are wasting away along the line of the work. Many of these engines never saw any kind of service, but were simply landed and left to go to ruin. They were built, for the most part, in Belgium, but others were made in the United States and in England.

There are scores of machine shops along the route of the canal, buildings for labourers and contractors, storage houses, hospitals,—houses for all conceivable purposes. They are built of wood, stone and metal. Some of them are sectional metal houses that were intended to be taken apart and moved from one part of the canal to another as occasion demanded. There are, all told, nearly 2500 such houses. The hospitals, too, are extensive in numbers and size, and they represent an investment of a huge sum of money. The finest of these structures of wood have withstood the ravages of time and neglect so well that they may serve a good purpose when operations are resumed. They were substantially built, and they are about the only things of the old Panama Canal Company that have retained anything like their former usefulness. The storage houses still contain many of their original supplies and in the machine shops there are still many tools in better condition than the machinery left to rot out of doors.

In the harbours and at the entrance to the canal steam craft of all kinds are also rotting in the warm, moist, dank atmosphere. These include costly steam dredges, tugs, floats, mud scows, pontoons, and many minor craft. Little attempt was made to protect or preserve any of these vessels from decay. The steam dredges have their buckets in the mud of the canal, in many instances where the cables rusted and broke apart. Decay is apparent on all sides.

It does not require any stretch of the imagination to see that this promiscuous piling up of machinery on the Isthmus at such an early stage in the progress of digging the ditch was a fatal mistake.

THE PLAZA IN THE TOWN OF PANAMA

In probably no other corner of the earth of similar size was there so much machinery to be found. Nearly everything to make a company of several thousand workmen independent of all the rest of the world was gathered there. Much of the machinery could never have been used, and its idleness in such a climate was fatal to its future value. In such a place constant vigilance in cleaning, repairing and protecting machinery is the price of success. Nowhere else probably will steel and iron deteriorate so rapidly as on the Isthmus of Panama. Its waste is to-day one of the saddest features of this gigantic undertaking.

At present, conditions are more favourable for a new company to undertake the work than ever before. There are housing accommodations that can be made fit for 15,000 to 20,000 workmen within a very short time. A railway runs the length of the canal route, with good terminal facilities and harbours at each end. There are hospital arrangements and supplies that can be quickly prepared for instant use.

Probably no canal route has been more exhaustively studied and surveyed in the past century than that of Panama. Persistently private and government commissions have been sent over the entire route, and each succeeding one has added to the general fund of information. The flow of the rivers, the rainfall, the temperature of the Isthmus, and the nature of the soil all along the route have been investigated and duly reported. Even the flora and fauna of the Isthmus where the canal will be cut through are known almost as accurately as if the territory were located at our very doors.

All of the now available scientific and engineering data will enable the new contractors and superintendents to lay the plans of their campaign with surer hand. The needs of the men who will invade the Isthmus will be better appreciated, and the supplies of medicines and hospital equipments will be a part of the first consignment of goods shipped to the scene of operations. Like an army moving upon a distant enemy, the commissary department and the hospital supplies will go along with the first con-

IN THE HIGHLANDS OF COLUMBIA

A STREET IN THE OLD QUARTER OF THE TOWN OF PANAMA

tingent of soldiers. It will indeed be an invasion of a strange country by an army of workmen that will be divided up into camps and regiments, each with its individual commander, and loads of supplies and implements. The whole campaign must be planned before the first move is made, and to avoid delays and mistakes the different detachments must follow in mathematical order. The estimated cost of the complete canal is placed roughly at $182,000,000. The completion of the work will be a matter of world-wide interest, and the wrecks of the past may not have been all in vain. Certainly something will be redeemed if the canal is finally opened to the commerce of the world.

SOME ELECTRIC FURNACE PROCESSES

By J. Wright

IT would be impossible, within the scope of a magazine article, to deal thoroughly with the many and various industrial processes which have been made possible by the intense heat available in the electric furnace. The writer, therefore, proposes to select the more important of these industries and deal briefly with each in turn, in an endeavour to interest the reader in the advances which have been made in practical electro-chemistry and electro-metallurgy by the introduction of the commercial electric furnace, first suggested, constructed, and exhibited by Sir William Siemens before what was the Society of Telegraph Engineers, in June, 1880.

Some of the leading types of electric furnace construction were described and illustrated in a previous article,* and the writer will, therefore, confine himself, in the paragraphs which follow, to a description of the various commercial processes carried out by their aid.

First, and foremost, comes the manufacture of calcium carbide, that chemical combination of calcium and carbon which, when brought into contact with water, gives off acetylene gas. The rapid growth and increasing popularity of acetylene gas lighting has, of course, been responsible for the enormous increase in the number of carbide factories, —an increase which, a year or two back, resulted in a supply of carbide being placed upon the market which was far in excess of the demand, the very natural consequence being that many of the manufacturers had perforce to shut down their plant, or, as an alternative, adapt their existing carbide furnaces to the manufacture of other and more marketable commodities.

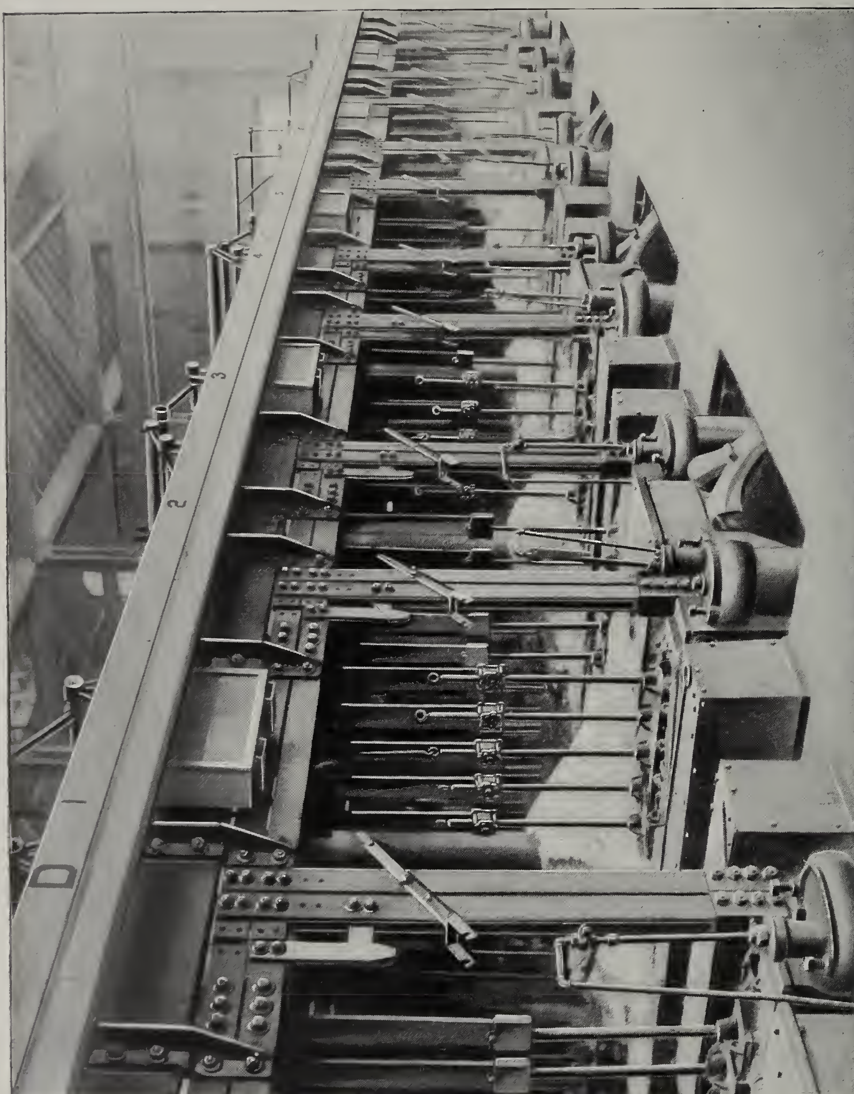
Calcium carbide was first manufactured economically, on a commercial scale, by a Canadian, T. L. Willson, in 1888. Although in reality a very simple synthetic process, there are many points connected with the manufacture of calcium carbide on a commercial scale which require more than passing attention, if an economical process and efficient yield be desired. The carbide is produced by heating together in the electric furnace a mixture of 65 per cent. lime (CaO) with 35 per cent. carbon, or coke (C).

A very high temperature,—5972 degrees F.,—is necessary to bring about the combination, in process of which the oxygen of the lime is liberated and unites with a certain percentage of the carbon present to form carbon monoxide (CO) and dioxide (CO_2) gases. The heat of chemical combination between the carbon and the calcium is, of course, present, but is insufficient in itself to render the mass self-heating. The lime fuses at the temperature of the electric arc and the carbon dissolves in it, forming calcium carbide; and it is instructive to note that the fusing point of the latter combination is actually below the temperature necessary to bring it about, so that the carbide, for some considerable time after its formation in the furnace, remains in a liquid, or semi-liquid, condition.

According to Mr. Horace Allen, the author of a statistical article on calcium carbide manufacture, which appeared in the *Electrical Review*, of London, for

* See "The Electric Furnace," CASSIER'S MAGAZINE, June, 1903.

THE ELECTRIC FURNACE ROOM OF THE INTERNATIONAL ACHESON GRAPHITE COMPANY, NIAGARA FALLS, N. Y.



THE ELECTRIC FURNACES OF THE ACKER PROCESS COMPANY AT NIAGARA FALLS, N. Y., ARE USED IN THE MANUFACTURE OF CAUSTIC SODA. THERE ARE 52 FURNACES, USING 9000 AMPERES OF CURRENT AT 300 VOLTS. AVERAGE VOLTAGE PER FURNACE, 6.4

January 5, 1900, the total heat required for the production of one pound of calcium carbide is 6249 British thermal units, which, expressed as electrical energy, are equivalent to 2.464 E. H. P.-hours, or 1.838 Board of Trade units. These figures are, in the main, theoretical, being based upon calculations made on known chemical and thermal data. The electromotive force required at the furnace terminals varies from 50 to 60 volts.

The condition in which the raw material should be fed into the furnace has been a matter for considerable controversy. Experience has demonstrated that a carbide furnace works at its best when fed with a raw mixture of coke and lime which has been reduced to granular form, rather than powdered. Extreme comminution of the charge is inadvisable in that, setting aside the principal question of the expense involved in thus reducing the ingredients to a powder, there remains the additional disadvantage that, when thus finely divided, the particles agglomerate around the electrodes, forming a coating which hinders the free escape of the gases formed in the reaction. In order to eliminate these various drawbacks, the adoption of a mixed charge, in which the particles have been reduced to the size of hazel nuts, is advocated. Statistics have been published from time to time by various authorities which go to prove that, whereas with a finely powdered charge three tons of the raw material are required for the production of one ton of carbide, only 1.7 tons are required in the production of a similar quantity when the charge is of a coarse or granular nature. The theoretical quantity of raw material required for the manufacture of one ton of carbide is 1.44 tons.

Estimates of the total cost of production of a given quantity of calcium carbide vary tremendously, as is only natural, being governed to a considerable extent by local conditions, the cost of power, material and labour. It is impossible in the limited space available to give even a summary of these various estimates; but the following statistics, contributed by Mr. Carl Hering to *L'Eclairage Electrique* in 1899, may be taken as typical:—

According to Mr. Hering, who bases his figures on the results obtained at Meran, in the Austrian Tyrol, it requires, theoretically, 1900 lbs. of lime and 1230 lbs. of carbon to produce one ton of carbide; in actual practice, 2050 lbs. of lime and 1420 lbs. of carbon are necessary. The cost of lime per ton was then about 16s., and of carbon 32s. One electrode suffices for 10 tons of carbide, and costs £6.12.0, or, approximately 13s. per ton. The electrical energy required per ton of carbide produced was 6400 E. H. P.-hours, which, at £2 per E. H. P.-year, works out at a little above £1.16.0 per ton. Accessory machinery, losses, etc., account for about 200 H. P., or 4s. per ton, the output being 6.5 tons per day. Labour, at 3s. to 3s. 4d. per day, amounts to 15s. per ton; amortisation and general expenses, £2 per ton; maintenance of plant, 6s. per ton. Summing up these various items, we arrive at a total cost of £7.5.0 per ton of carbide produced.

The manufacture of aluminium is probably the next most important industry involving the employment of electric heat. The apparatus employed, however, does not constitute a furnace pure and simple in the ordinary acceptation of the term, in that electrolytic action enters into the process. But considerable heat is also required to bring about the reduction ; hence the appended particulars.

There are two well-known processes for the manufacture of aluminium from alumina, which, in the main, bear a striking resemblance to each other. In Hall's process, the alumina, prepared from bauxite, is continuously dissolved in a bath of potassium fluoride. In Heroult's process, the alumina is dissolved in cryolite, a double fluoride of aluminium and sodium. The type of furnace employed, together with the mode of procedure, has already been described in a previous article by the writer, referred to earlier. But the following additional facts concerning it may prove of interest.

The current density employed in the

furnace is about 700 ampères per square foot of cathode surface, amounting to about 8000 ampères per furnace. According to Mr. J. W. Swan, the power required in practice is 14 E. H. P.-hours per pound of aluminium. Theoretically the yield should be a third of a pound more; there is, therefore, considerable loss, and room for further improvement in the efficiency of the process.

As already intimated, a necessary preliminary to the manufacture of aluminium is the preparation of alumina from the crude bauxite. A comparatively recent patent (August 14, 1903) taken out by Mr. C. M. Hall, of Niagara Falls, relates to a process for effecting this with the aid of the electric furnace. The bauxite is mixed with a small percentage of carbon and is calcined, after which sufficient carbon is added to bring the total proportion up to from 8 per cent. to 10 per cent. A small quantity of ferric oxide, to enrich the ore, and, in some cases, a flux, such as lime, soda or cryolite, is added, and the whole is intimately mixed with a certain quantity of powdered aluminium. The mixture is then subjected to prolonged fusion in the electric furnace, under which treatment a certain proportion of the added aluminium enters into combination with the iron, silica, and other foreign metals present to form an alloy which sinks to the bottom and is tapped off, leaving pure alumina. The latter is allowed to cool, after which it is pulverised and then subjected to magnetic separation, being then ready for conversion into metallic aluminium in the usual manner.

The manufacture of carborundum, the carbide of silicon (SiC), is probably the simplest electric furnace process. It consists in a direct combination of the two elements, carbon and silicon, under the influence of electric heat, and is carried out in a temporary furnace structure worked on the resistance principle. The furnace itself is loosely built of firebrick, and is dismantled at the end of each run. No cement of any kind is used in its construction, all interstices being left open, in order to provide for the free escape of the gases formed in the process of combination. The furnaces in use at Niagara Falls by the Carborundum Company, who are the sole manufacturers, are 16 feet long, 6½ feet wide, and 5 feet deep. In these the raw material is packed to a height extending about 4 feet above the top of the furnace.

Each furnace consumes 1000 E. H. P. The process of conversion occupies thirty-six hours, and the electromotive force at the furnace terminals is approximately 50 volts. Current is led into the furnaces through the medium of heavy bronze terminal castings, to which the cables are connected; these castings support, inside the furnace chamber, two bundles of carbon rods, to the number of sixty in each bunch. The rods are each 3 inches in diameter and 2 feet long, and, collectively, form an electrical connection between the metal terminals and the furnace charge which is packed around them.

The raw charge consists of 34.2 per cent. coke, 54.2 per cent. sand, 9.9 per cent. saw-dust, and 1.7 per cent. common salt, its total weight being approximately ten tons. Only about two tons of carbide are produced at each run, as against a theoretical yield of over four tons, from which it will be seen that the efficiency of the process is very low.

During the process carbon monoxide gas is given off, and burns with a blue flame at the various openings. At the conclusion of each run the furnace, as already stated, is pulled to pieces, the charge having first been allowed to cool. The contents are then found to consist roughly of three layers, the outer one being a mixture of volatilised salt, silica, and carbon; the middle one, a mixture of amorphous silicon carbide and uncombined raw material, which is worked up into the next charge; whilst the centre, or layer immediately surrounding the core, is carborundum, about 16 inches thick. The core itself, constituting a bridge between the two electrodes, is graphite, produced from the original coke under the intense heat.

Mr. E. G. Acheson, the inventor of the carborundum process, has utilised this latter feature in a later patent for graphitising electrodes in the furnace.

The form given to the latter by the International Acheson Graphite Company, of Niagara Falls, who work the patents, bears a striking resemblance to that of the carborundum furnace described above.

The process of graphitising consists in causing the pure carbon, under the influence of heat, to combine with certain impurities which are present in the mass prior to the process. The temperature necessary for the reaction is higher than that required for the decomposition of the carbides formed. The furnace charge may consist of either cylindrical rods or rectangular plates. In the former case, the rods are packed transversely to the direction of current flow, the necessary high resistance path from one to the other being established along the line of contact between the cylindrical surfaces. It is chiefly along these lines that the heat is generated, and this mode of packing the articles to be graphitised results in the production of exterior heat rather than in the mass itself, as would be the case were the articles arranged with their axes parallel to the line of direction of the current. This constitutes the principal feature of the invention, and effects a considerable economy in the current required for the operation of the furnace.

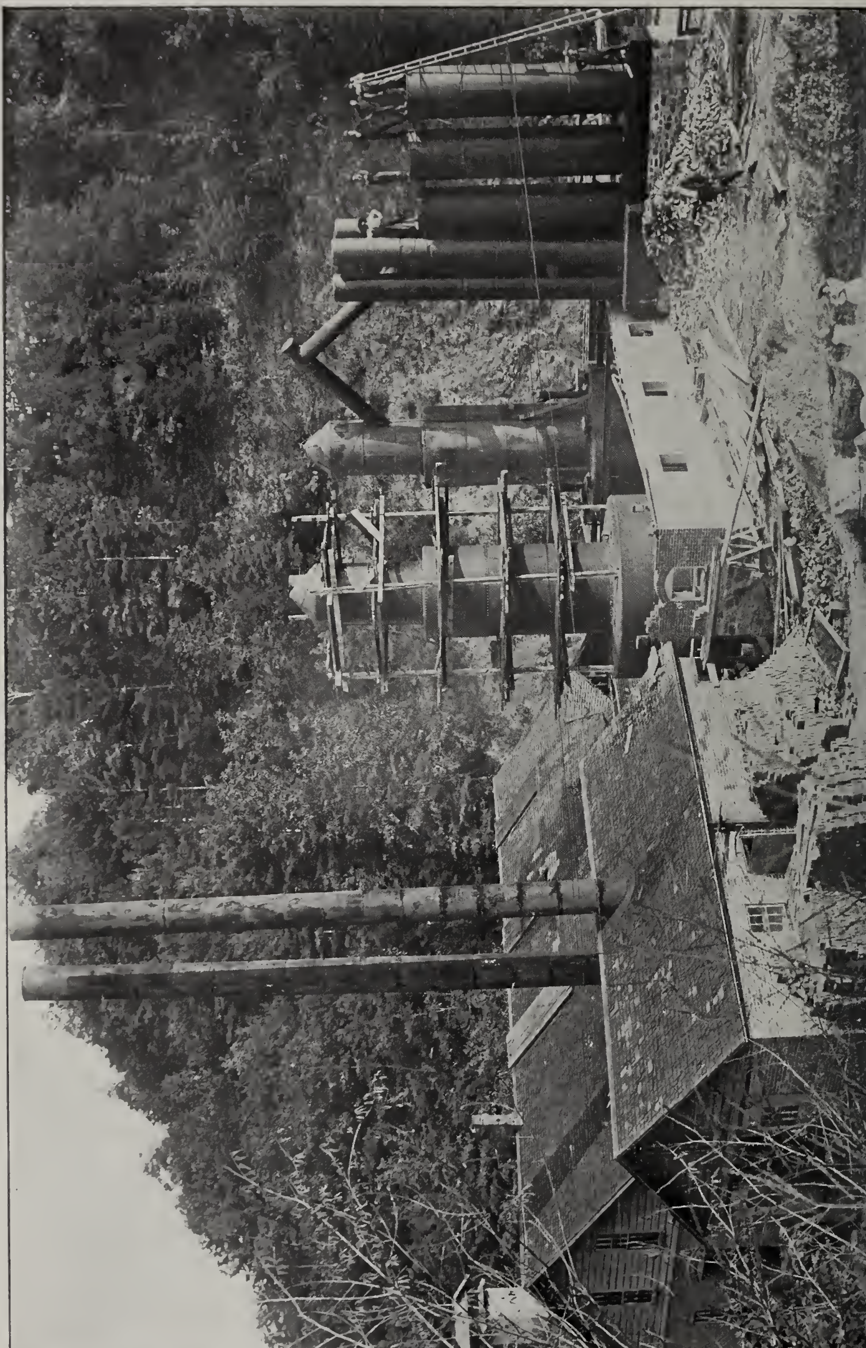
If the objects to be graphitised are rectangular, they are arranged in a series of regular piles along the path of the current, each pile being separated from its neighbour by a filling of pulverised coke. The latter is also employed as a filling around the cylindrical rods in the former case, and between the ends of the charge and the electrodes. The base of the furnace is lined with a refractory layer of carborundum, or similar conducting material, and the whole is covered in at the top with a layer of ground coke and sand.

Carbon, in the form of coke, is largely used as a reducing agent in metallurgical operations, a necessary feature of which is that the carbon, or coke, so used shall be free from impurities, such as silica and the compounds of silicon, which would, if present, combine with the metal under treatment, and result in the re-introduction of like impurities into the finished article. This fact led Mr. C. M. Hall, the patentee of the aluminium process which bears his name, to devise a form of resistance furnace for ridding the coke of these undesirable impurities before it is employed in connection with the extraction of metals.

The process, as patented by him, consists in powdering the coke, and mixing it intimately, whilst thus powdered, with a metallic fluoride, such as sodium fluoride, cryolite, or fluor spar. This mixture, when subjected to heat in a suitable furnace, becomes pure carbon, owing to the reaction set up between the fluoride and the compounds of silicon, which combine to form silica fluoride, the latter being driven off in the form of gas.

By adding a suitable proportion of pitch to the mixture, as a binding material, it can be moulded into electrodes of any desired form, and the purification and baking processes thus carried out in one operation of the furnace. The latter is built of brick and filled with the moulded carbon blocks, packed symmetrically, and insulated from one another by suitable packing. Through the centre of the mass, and in close proximity to the blocks, passes a resistance core with end electrodes. An alternating current is supplied to this core by way of the latter, and the heat is adjusted to any desired temperature by varying the current. The actual temperature is necessarily slightly higher than that required for baking alone, in order to produce the requisite thermochemical action for the purification of the carbon.

Carbon bisulphide is another product of the electric resistance furnace, its manufacture being carried out on an extensive scale at Penn Yan, New York, U. S. A. The furnace used is illustrated in Fig. 1. It is the invention of Mr. E. R. Taylor, and is the outcome of considerable forethought and experiment. In the original furnaces independent carbon electrodes were utilised as terminals, being protected from a too rapid combustion by broken carbon which was fed into the furnace through orifices immediately surrounding the electrodes.



ELECTRIC FURNACES AT PENN YAN, NEW YORK, FOR THE MANUFACTURE OF BISULPHIDE OF CARBON

In the latest type of bisulphide furnace the carbon-block terminals have been entirely dispensed with, electrical connection being made directly with the metallic feed hoppers through which the broken carbon is introduced into the furnace.

In brief, the action is as follows:—The upper cylindrical portion is filled with closely packed carbon *C*, through which the sulphur vapours produced by the action of electric heat upon the fused mixtures of carbon and sulphur at the hearth or crucible portion of the furnace CS_2, rise, and, in passing, become converted into carbon bisulphide, which is suitably collected and condensed. Terminal connection with the furnace is secured through the metallic hoppers *MM*, which are four in number, situated at equal distances around the circumference of the hearth, and through which a constant supply of broken carbon is fed.

The raw sulphur is made to perform a primary duty before finally entering into chemical combination with the carbon in the furnace to form carbon bisulphide. It is fed in, cold, through hoppers *HH*, which convey it into annular chambers entirely surrounding the furnace body and hearth; in these, the sulphur, whilst still in a cold state, acts as a heat-conserving jacket, and becomes molten only when it approaches the bottom of the annular chambers which communicate with the furnace hearth, and through which the sulphur feed is effected. It thus reaches the centre of activity in a heated condition, and no undue lowering of the general temperature results. By varying the electrical connections to the four terminal hoppers, a very thorough and complete fusion of the carbon and sulphur is effected in the region of the hearth.

The dimensions of these furnaces, as used at Penn Yan, are,—height, 41 feet; diameter, 16 feet. They require a current of 4000 ampères at from 40 to 60 volts, to operate them. The regulation is, to a certain extent, automatic; as the temperature, and consequently the degree of fusion, increases, more molten sulphur flows into the bottom of the hearth from the sulphur jackets, and the level of the molten mass rises until it encircles the electrode hoppers and gives rise to an increase in the electrical resistance of the active column, with a consequent decrease in the current, until the working conditions again become normal. Experiments in 1902 showed an output of 10,000 lbs. of carbon bisulphide per furnace in twenty-four hours, but this figure has since been considerably increased.

Among modern industrial processes which have benefited by the introduction of the electric furnace may be cited the

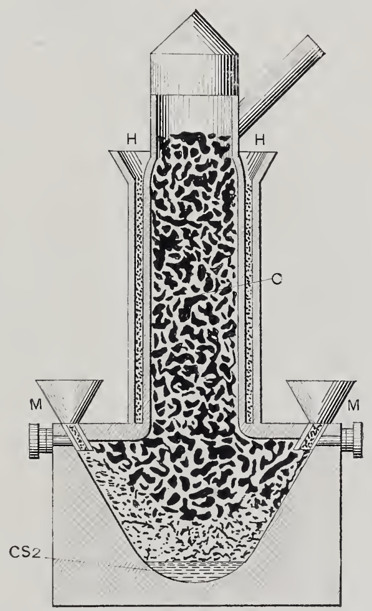


FIG. I.—A BISULPHIDE OF CARBON FURNACE

manufacture of calcium and strontium. Here, again, as in the case of aluminium, the processes are partly electrolytic. Calcium, as is well known to the chemist and metallurgist, is of great value in various industries as a reducing agent, the only drawback to its widespread use being its present comparatively high market value, which makes it unavailable for all but experimental purposes, where the question of cost is, within certain limits, no object.

The high price charged for the metal

calcium is due to the expensive method of production, which consists in subjecting a dilute solution of calcium chloride to electrolysis in the presence of a mercury cathode: an amalgam of calcium with mercury is thus obtained, from which the mercury is subsequently

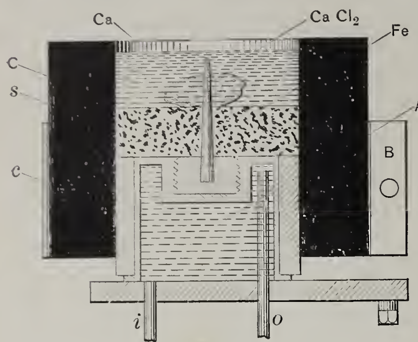


FIG. 2.—MAKING METALLIC CALCIUM

driven off by heat. Apart from the cost of the process, pure calcium is never produced by this method, a small percentage of metallic mercury being always present in the resultant product.

Messrs. Borchers and Stoekem, recognising the need for a cheaper and more efficient method of production, turned their attention to the possibilities offered by an electric furnace method, and recently succeeded in designing an electrolytic furnace in which pure, metallic calcium is readily manufactured from its fused chloride.

The fundamental principle involved consists in the employment of a small cathode and correspondingly large anode, between which the fused mass is brought to a red heat, when the metallic calcium makes its appearance around the former as a spongy mass. On removing this latter from the furnace and immersing it in petroleum, a porous residue is obtained, from 50 per cent. to 60 per cent. of which consists of pure calcium. The mass is compressed, or squeezed, whilst still warm, in order to get rid of the chloride with which it is still saturated, and a product, containing fully 90 per cent. of pure metal, is the result. The latter is then fused in an hermetically sealed chamber, and thereby converted into a firm silvery mass of metallic calcium. Calcium is claimed to have been produced by this method at a cost of approximately 1s. 6d. per pound, about one five-thousandth of the cost of the original process.

To pass on, however, to a consideration of the furnace employed, let us turn our attention to Fig. 2, which represents a diagrammatic section of the latter. It consists of an outer carbon cylinder *C* built up of several longitudinal sections, each keyed into its neighbour, and the whole held together by a metal ring or band *B*, which at the same time constitutes a terminal connection, the carbon cylinder being the anode.

The upper portion of the cylinder is open, whilst its lower end is closed by a fire-clay cylinder *c*, surrounding and insulating a metal chamber *A*, which performs the double office of a circulating water tank for cooling purposes, and a support for the cathode *Fe*, which consists of an iron rod placed axially with regard to the cylindrical anode, and screwed, at its base, into the upper por-

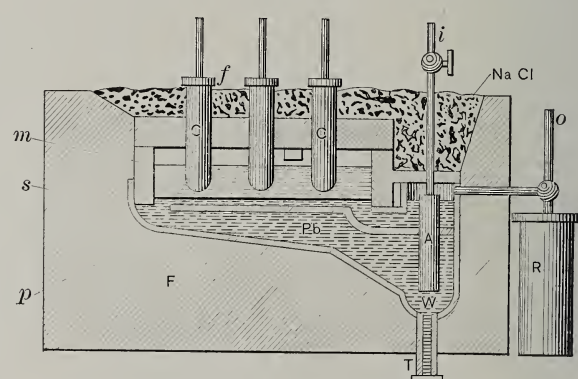


FIG. 3.—THE ACKER FURNACE FOR CAUSTIC SODA

tion of the cooling chamber *A*. Inlet and outlet pipes, *i* and *o*, respectively, serve to convey the water to and from the tank, whilst it is protected from the heat of the furnace by a layer of fluorspar *s*, which, owing to its high melting point, remains solid during the opera-

tion of the furnace. The mass of calcium chloride, $CaCl_2$, is placed above this, the action of the furnace being started by several thin carbon rods, placed radially, like the spokes of a wheel, between the iron cathode *Fe* and the inner surface of the carbon cylinder. The heat set up by the flow of current through these rods serves to start the fusion of the upper layer of chloride, and they are subsequently removed, leaving the process of electrolysis to continue through the initially fused mass. The position taken up by the resultant spongy calcium is indicated in the figure by *Ca*.

The apparatus for the manufacture of strontium is, with some slight modifications, incidental to the properties of the separated metal itself, similar to that detailed here for the production of calcium. Unlike the latter, strontium separates out from its compounds in the form of small, spherical masses, which tend to rise to the surface of the molten salt and there again enter into chemical combination with the chlorine from which they have just been liberated.

To obviate this drawback, the iron cathode is made shorter, so that its upper extremity reaches only to a point just above the lower edge of the cylindrical carbon anode. The latter rests upon a circular fireproof structure of insulating material, such as fire-clay, which, in turn, is supported in a cup-shaped depression in the upper portion of the cooling chamber. Unlike the former case, the cooling chamber itself is, in the strontium furnace, given a larger diameter than the carbon anode, and it is in the central depression or basin around which the anode rests that the metallic strontium collects during the action of the furnace, and is solidified by the cooling effect of the circulating water.

Another partially electrolytic furnace process is that exploited by the Acker Process Company, at Niagara Falls, in the manufacture of caustic soda from fused electrolytes. The Acker electrolytic furnace is shown in section in Fig. 3. It consists essentially of a rectangular trough-like structure or hearth *F*, having a steel base *s*, refractory side walls *m* of magnesia, and a removable horizontal false bottom, or dividing partition *p*, also of steel. A flue *f* provides for the escape of the chlorine gas evolved during the process, which may be utilised for the manufacture of bleaching powder, whilst one end of the structure slopes to a well *W* fitted with an injector *A* for the introduction of steam under pressure. The cathodic, or negative electrode, connection with the source of current is made through a metal tube *T*, communicating with the well *W*. The anodes *CC* are cylindrical graphite rods, projecting vertically through the cover to within a short distance of the steel partition *p*. $NaCl$ is a mass of the raw material sodium chloride, or common salt, which is packed on the top of the furnace, and performs a triple duty, viz., that of conserving the heat generated, hermetically sealing all except the legitimate gas outlets, and providing a source of supply as the charge becomes exhausted. *Pb* is a mass of molten lead extending upwards to a level slightly above that of the false bottom or partition *p*, and in electrical connection with the cathode.

The process of operation is as follows:—Steam being admitted to the injector through the inlet pipe *i*, carries up with it, from the base of the injector well, a mixture of lead, caustic soda, and hydrogen gas, the resultant products of the electrolytic process going on in *F*. On reaching the upper chamber above the well *W*, these three constituent products part company, the alloy flowing back over an inclined partition into the main furnace *F*, whilst the caustic liquid passes over into the receiver *R*. Hydrogen gas is available at the outlet *o*, and may be utilised for a variety of purposes, chief among which may be mentioned its application to an oxy-hydrogen burner, or burners, for the preliminary fusion of the charge.

The following facts in connection with the Acker process, as carried on at Niagara Falls, were given by the inventor in a paper read by him before the American Electrochemical Society at Philadelphia in 1902:—Each furnace has

four anodes, and consumes a total current of 9000 ampères, or 2250 ampères to each anode, representing a current density of about 3100 ampères per square foot.

The efficiency of the process is 100 per cent., and the works have been in continuous operation since 1900, with but few temporary accidental interruptions. The anodes do not wear away in use, and the only trouble experienced is said to have been in the electrode connections at the carbon-copper junction, the metal being gradually corroded or eaten away. An improved method of construction has, however, minimised this drawback.

The Darling electrolytic furnace process, which is employed in the manufacture of nitric acid and metallic sodium from nitrate of soda, is comparatively simple. The anode consists of an outer iron vessel, within which are placed two concentric cylinders of perforated iron. A shunt connection between these latter and the outer iron anode protects them from injury during the action of the furnace, whilst the space between the two perforated walls is filled in with magnesia. The fused salt is contained within the inner of the two cylinders, the cathode, a carbon rod, being immersed in it. Nitric acid gas is set free in the outer space between the walls of the anode and the concentric cylinders, and is conveyed by an outlet pipe to condensing apparatus where it is converted into the liquid acid. The sodium, on the other hand, rises to the surface of the fused salt contained within the inner perforated cylinder, whence it is removed at intervals by means of a ladle, and placed in tin vessels containing a small quantity of paraffin, which effectually protects it from the action of the atmosphere. The fall of potential between the terminals of each furnace whilst the operation is in progress is 15 volts.

The process patented in 1901 by Alfred H. Cowles for the manufacture of aluminium-bronze in the electric furnace, though far from efficient, presents several novel points. The furnace consists of a porous carbon crucible, hermetically sealed by a close-fitting lid, through which passes a carbon rod. This latter, and the crucible itself, constitute the two electrodes. Volatile products resulting from the reduction in the crucible pass through the porous walls of the latter, under pressure of the gases produced in the reaction, and are condensed on the inner walls of a cooling tank or water-jacket, which surrounds the crucible, and, with it, forms an annular space in which the volatile product is collected. In order to prevent clogging of the pores in the walls of the crucible a very high temperature is necessary.

Phosphorus is another comparatively recent product of the electric furnace. The form of construction designed by Messrs. Readman and Parker for this purpose has already been dealt with in a previous article; it is employed at Niagara Falls and at Oldbury, England, by Messrs Albright & Wilson. It was patented in Great Britain in 1888, and consists, briefly, in heating, by means of a resistance furnace in which the charge itself constitutes the resistance column, an intimate mixture of phosphates and carbon, together with a suitable flux, the terminal electrodes being of carbon. The capacity of the furnaces is 1½ cwt. of phosphorus per furnace per day. The process is fairly economical, in that from 80 to 90 per cent. of the phosphorus contained in the charge is recovered. In 1898 the Oldbury works utilised 700 H. P. and the Niagara works 300 H. P. in the manufacture of this element, but the plant and output have since been considerably increased.

Similar plants are in existence in Geneva, Switzerland, and Greisheim, Germany, in which latter country the refusal of patent rights has left the electric furnace method open to all comers.

The Machalske electric furnace process for the manufacture of phosphorus, invented by Dr. F. J. Machalske, of Long Island City, New York, and exploited by the Anglo-American Chemical Company, is illustrated in Fig. 4. The furnace consists of a central chamber or crucible *C*, 36 inches by 12 inches by 18 inches, built up of carbon blocks,

and lined internally with calcined magnesia and a special mixture, whilst outside it is jacketed with fire-clay, red brick and a mixture of borax and asbestos flour. The upper electrode *E* is mounted in a special holder or clamp *A*, and provided with a hand-wheel and

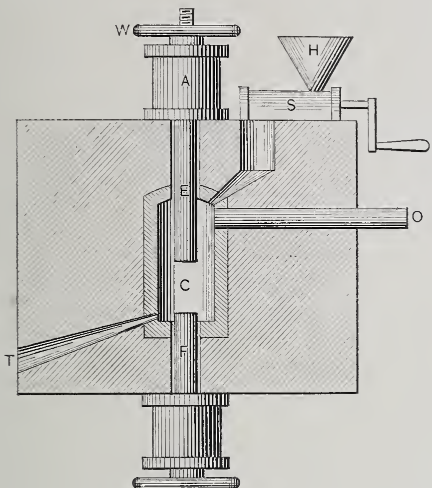


FIG. 4. THE MACHALSKE FURNACE FOR MAKING PHOSPHORUS

worm *W* for feed adjustment. It is 4 inches in diameter and 8 feet long. The lower electrode *F* passes vertically up through the floor of the furnace, and is also provided with a screw and hand-wheel adjustment, as shown. The raw material, or phosphate, is placed in the hopper *H*, and is fed into the furnace chamber by the screw conveyor *S*. Once the action is started, the arc can be drawn out to as great a length as 15 inches. An alternating current is employed, with a voltage ranging from 30 to 120 volts. Each furnace takes from 1000 to 4000 ampères, and a temperature of 7000 degrees F. is available within five minutes of switching on.

A molten slag, consisting mainly of calcium silicate, is produced and is run off at the tap hole *T*, whilst the phosphorus is driven off as vapour, and passes, by way of the outlet *O*, into suitable condensers, where it solidifies in the form of dark yellow shavings. These are subsequently treated with sodium hypo-bromide, whereby the red phosphorus is converted into yellow and impurities are eliminated.

In the Machalske furnaces, as described above, 150 lbs. of the raw phosphate can be treated in a quarter of an hour, yielding yellow phosphorus at about 3½d. per pound, reckoned on a basis of 2d. per Board of Trade unit. Two of these furnaces, each consuming 2000 ampères, are in use by the Anglo-American Chemical Company for the manufacture of yellow and red phosphorus.

One of the more recent applications of the electric furnace is in the manufacture of glass, a process which entails considerable expenditure of heat and a comparatively clean source for the latter, such that no impurities in the shape of combustion products shall enter into the fused mass and destroy the purity and transparency of the finished article. Nernst's discoveries in connection with earths that become electric conductors when heated to a certain degree have an

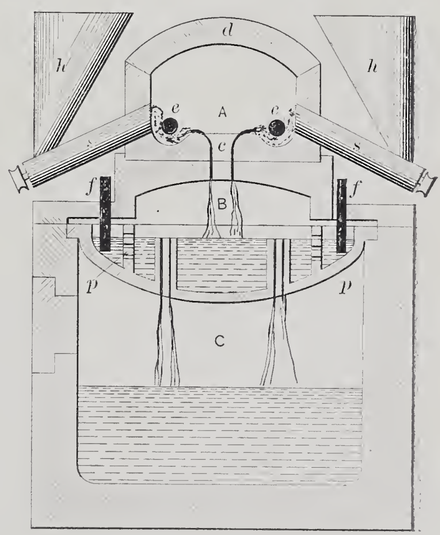


FIG. 5. THE VOELKER ELECTRIC GLASS FURNACE

important bearing on the development of this industry, in that glass itself may be numbered among those substances; molten glass is, in point of fact, an electrolyte, and thus lends itself readily to electric furnace methods of manufacture.

One of the earliest electric furnaces

for glass production was patented in Germany in 1882 by Messrs. S. Reich & Co. It was of the resistance type, and consisted essentially of a carbon crucible, open at the base, and lined internally with a net or bag of platinum wire. The raw material was fed into this, and having been fused by the heat developed in the carbon walls, dripped through into refining vessels placed underneath.

The furnace invented by August Voelker, of Ehrenfeld, is represented in Fig. 5, and is a combination of the arc and resistance principles of electric heating, the upper portion *A* being utilised as an arc furnace for melting the raw materials, and the intermediate *B* as a resistance furnace for a species of refining process which the molten mass subsequently undergoes before it finally overflows into the lower receptacle, or trough *C*.

The arc furnace *A* is constructed of refractory material, and has a dome *d* which reflects the heat of the arc set up between the two electrodes *e e* on to the raw material, which is fed by screw conveyors *s s* from the hoppers *h h*, and delivered, as shown, just beneath the electrodes. The mass, having been fused by the reflected heat of the arc, flows down the central opening or chimney *c* into the intermediate resistance furnace *B*, which is subdivided by the vertical perforated partitions *p p* into one central and two outer chambers. In these latter are placed the two electrodes *f f* of the resistance furnace, the circuit between them being completed by the molten glass. The object of the partition is to prevent contamination of the fluid mass by particles which might become detached from *f f*.

In this intermediate chamber the glass becomes more fluid, and the bubbles of air and gas, carried over by it from the first fusion in *A*, are driven off. It then overflows into the cavity *C*, whence it is drawn off as pure glass, and is ready for use as such.

A glass-making arc furnace invented by Albert A. Shade, of Chicago, consists of an inclined tubular hearth, running through a fire-brick support or base, and provided at its upper and lower extremities, respectively, with the usual hopper and screw conveyor for feeding the raw material, and a tapping orifice for drawing off the molten product. Disposed axially throughout the length of the tube are several pairs of electrodes, between which the necessary heat is developed. A preliminary heating of the charge is accomplished by the aid of several gas burners in the upper portion of the furnace, whilst a series of magnets and iron shields, fixed in recesses provided for them in the hearth, serve to direct the various arcs downward on to the charge as it passes through.

The Bronn process for the manufacture of glass in the electric furnace has been devised with a view to overcoming several of the drawbacks incidental to a continuous process, chief among which may be mentioned the splitting up of the continuous charge, whilst passing through the furnace, into unequal masses, and a consequent lack of homogeneity in the manufactured product; contamination of the molten glass by particles detached from the electrodes, etc.

The general principles of construction and operation of the Bronn furnace, in-

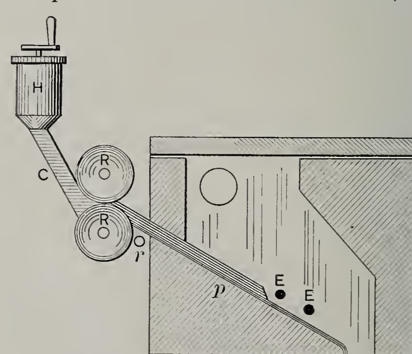


FIG. 6. THE BRONN ELECTRIC GLASS FURNACE.

vented by J. Bronn, of Köln, Germany, are represented in Fig. 6, in which *H* is a hopper, in which the raw material, in the form of powder, is mixed with a suitable binding substance, such as waterglass, hydraulic lime, or plaster, which will not affect the transparency or purity

of the resultant glass. The mixture is fed down the chute *C* to the rollers *R R*, between which it passes, and is thereby transformed into a continuous and homogeneous sheet or rod, as the case may be, the particles being held together by the water-glass or lime before mentioned. It next passes over a heated roll *r*, which drives off all moisture, and finally emerges on the upper extremity of an inclined plane *p*, forming the hearth or floor of the furnace. Down this it travels at a regular rate, dependent upon the speed of fusion and consequent glass formation, passing for that purpose under the arcs playing between the electrodes *E E*, or, if in rod form, travelling down the hearth in like manner between opposite pairs of arc electrodes.

F. A. Becker's method of glass manufacture in the electric furnace calls for the use of three arcs, arranged one below the other, to form a series of steps. The first two arcs consume 100 ampères, and effect the necessary fusion of the raw materials, whilst the third, situated at the lowest point, takes 50 ampères, and serves to maintain the fluidity of the molten glass. The voltage employed is 40, and the current, owing to the fact that a direct or uni-directional flow decomposes molten glass, is alternating in character.

Last, but by no means least, of the many industrial applications of the electric furnace, only a few of the principal ones of which have been included here, is the smelting, or reduction of metalliferous ores, and the manufacture of steel. As typical of the former, the reduction of arsenic ores may be cited. The importance of arsenic as a marketable commodity may be gauged from the facts that the total output for 1900 was 7300 metric tons, produced by Great Britain, Germany, Italy, Spain, and Canada, the two first-named being the principal manufacturers. The demand is said to be quite equal to the supply, so that there is little doubt as to the need for this useful metal.

Unfortunately, the ordinary metallurgical processes for its extraction from the various arsenic-bearing ores possess many attendant disadvantages, not the least of which arise out of the poisonous nature of the fumes given off during the process and their deleterious effect on the surrounding animal and vegetable kingdom. This is all the more unfortunate in that many of the well-known arsenic-bearing ores are also rich in gold and other precious metals. An improved process, therefore, calculated to increase the output and efficiency of extraction, would doubtless be welcomed by metallurgists in general.

Such a process, applicable to at least one rich grade of arsenic ore, has been invented by Mr. G. M. Westman, of New York. It comprises, in effect, a resistance furnace process, and the ores capable of treatment by it are known as "mispickel," or arseno-pyrite ores, which also contain ores of gold, silver, and other metals of value. They are very rich in arsenic, averaging 46 per cent. by weight of that metal, which exists in the form of sulpho-arsenide of iron ($FeS_2 + FeAs_2$).

The process of reduction consists in heating the ore electrically in a closed furnace from which atmospheric oxygen is hermetically excluded. The iron combines with the sulphur, forming ferric and ferrous sulphides, which are thrown down in the form of a fused matte, and include the precious metals, while the arsenic itself is liberated as a heavy metallic vapour and is collected in suitable condensers as a fine metallic powder. The process is carried on in a circulating atmosphere of nitrogen gas, formed in the first place from the atmosphere, by extracting the oxygen by combination with a small quantity of arsenic vapour to form the oxide. Once produced in this manner, the same volume of nitrogen is, by circulation, used repeatedly in the furnace.

The general construction of the latter is shown in Fig. 7, in which *F* is the furnace proper, with a refractory hearth or lining *R* of fire-brick. In this are embedded the two cast-iron electrodes *E E*. A central hopper *H* serves for the introduction of the ore, but, at the same time, prevents ingress of air; *M* is the mass of fused ore, which consti-

tutes the resistance path between the electrodes; *C C C C* are condensers, with bottom traps *t t*, in which the powdered arsenic collects and from which it is removed. The tube *T* completes the circulatory system for the nitrogen gas, which is kept in motion by a mechanically-driven blower *B*. This latter is reversible, so that when one set of condensers becomes heated the current of gas may be reversed, and the heat energy thus stored up utilised for maintaining the general temperature of the furnace, which would otherwise tend to fall.

An exhaustive test was conducted on an experimental furnace of this type by Mr. Carl Hering several years ago. The process, owing to the small size of furnace employed, was naturally wasteful of energy; but, by measurement of some losses and computation of others, a fair estimate of the probable cost of reduction in a larger furnace was arrived at. An alternating current of 8000 to 10,000 ampères, at a periodicity of 120, was used, the electrodes, which, as already stated, were of cast iron, being about 6 square inches in cross-sectional area, and rather long. The losses, amounting to more than half the energy supplied to the furnace, were due to several contributory causes, viz., skin effect, hysteresis, resistance, Foucault, or eddy currents, and conduction. The losses in leads alone, from the secondary of the transformer to the furnace terminals, amounted to 44 kilowatts, whilst 9 to 10 kilowatts were lost by radiation and conduction.

In one trial 185 lbs. of ore were supplied to the furnace in the hour, the power consumed in the conversion being about 105 kilowatts; the current varied from 4000 to 8400 ampères, and the voltage from 12 to 22 volts, representing a rate of approximately 1140 kilowatt-hours per 2000-lb. ton of ore. According to Mr. Hering, it is quite safe to assume that in a large, well-designed furnace the power required in the reduction process would not be more than 1000 kilowatt-hours per 2000-lb. ton of ore. The theoretical heat energy required has been variously estimated at from 200 to 400 kilowatt-hours per ton, which indicates a margin for improvement.

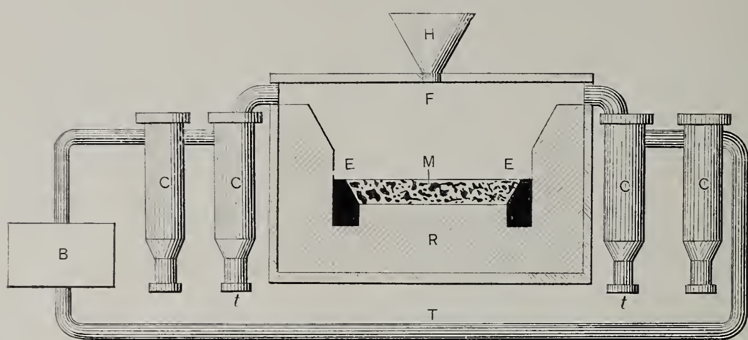


FIG. 7. THE WESTMAN FURNACE FOR TREATING ARSENIC ORES

The patent rights in Mr. Westman's process are the property of the Arsenical Ore Reduction Company, of Newark, New Jersey, who are applying it to the large deposits of ore in what is known as the Big Dan claim in Ontario, recently acquired by them.

Rumour has been rife during the last year or two regarding the Stassano electric furnace process for the production of iron and steel. This consists, in brief, in first subjecting the ore to a process from which it emerges in a state of fine subdivision. Lime and coke, also ground to a fine powder, are then mixed with it in the necessary proportions, and the mixture, aided by a suitable binding material, is moulded into briquettes, in which form it is subjected to heat in specially designed arc furnaces. The process is a continuous one, the resultant

metal and slag being tapped off at regular intervals. An experimental plant was installed at Cerchi, in Italy, the furnace being about 10 feet high, and calling for an expenditure of 1800 ampères at 50 volts for an output of 66 lbs. of metal per hour. In the original experiments with the Stassano process 1 kilogramme (2.2 lbs.) of manganiferous steel involved the expenditure of 4.08 E. H. P. hours; this figure has, however, since been reduced to 2.7 E. H. P. hours for an equivalent output.

The Gysinge process of electrical steel production, also somewhat largely spoken of, is now carried out on a commercial scale at Gysinge, Sweden. The works occupy the site of the original Gysinge sulphite factory, which was burnt down in 1901. Experimental trials have demonstrated that in a furnace having a capacity of about 400 lbs. of raw ore, from 1300 to 1500 lbs. of steel can be produced in twenty-four hours. The power is derived from a direct-coupled, turbine-driven generator of 300 H. P., and the new furnace has a capacity of 4000 lbs., with an estimated output of 1500 tons of steel per annum. The finished product is said to be of excellent and uniform quality, but further details regarding the actual process are lacking.

In 1901 a French patent was taken out by the Société Électrométallurgique Française on an arc furnace for the manufacture of all varieties of iron and steel in one operation, by the direct treatment of specific mixtures of iron ore, carbon, and such other ingredients as are determined by the nature of the product required.

The furnace construction is very simple, consisting of a refractory structure or crucible provided with a domed cover of loose fire bricks, which can be removed for charging purposes, and through which pass two similar vertical electrodes. These latter do not extend to the bottom of the crucible, but only to a level with the upper tapping hole provided for the removal of the slag formed in the smelting process. The molten metal collects at the bottom of the crucible below the level of, and consequently out of contact with, the electrodes, and is drawn off at a separate tapping hole situated at the lower point of the hearth.

As already intimated, the writer has, in the preceding paragraphs, touched but lightly upon some of the leading industrial applications of the electric furnace. The brief programme thus gone through must not by any means be regarded as representing the entire field of utility covered by the latter. New uses and applications are constantly being found for it, and it has every prospect of increasing popularity in an industrial field far beyond the comparatively limited scope of its rivals.

FUEL ECONOMY IN STEAM PLANTS

FROM THE CHEMIST'S POINT OF VIEW

By John B. C. Kershaw, F. I C.

FOR the purpose of discussing the fuel economies which, as a chemist, the writer believes to be attainable in connection with the raising of steam in large engineering plants, he will divide the subject into three sections:—1. The supplies of fuel and water; 2. The combustion of the fuel in the boiler furnace; and 3. The waste gases from combustion.

FUEL SUPPLY

When the chemist regards the conditions under which the manager in charge of a large steam generating plant arranges his contracts for thousands of tons of fuel, to be delivered over a period of some months, he must be struck by the absence of any effective means for checking the quality of the deliveries of the selected fuel. Fuel appears to be the only raw material of which the sale is conducted by what may fairly be called rule-of-thumb methods in place of scientifically exact tests.

Steam-raising trials are generally made with sample waggons of various fuels before the contract is signed, and the selection is based upon the results obtained in these trials. Here, at the very basis of the system of selection, there is wide scope for uncertainty and error. The comparative wetness or dryness of the fuel as it is discharged into the boiler house; the humidity and temperature of the atmosphere and the direction of the wind,—all causes which influence the pull of the chimney;—the state of the boiler as regards scale; and, finally, the skill and reliability of the fireman, all are factors which have great influence upon the results obtained in these steam-raising trials. The reliability of the fireman is probably the most important factor, though many engineers do not appreciate this. Even where mechanical stokers are employed, the fireman in charge has much influence on the results obtained. In these days of secret gifts and commissions to men in nearly all positions, a small present to a fireman or to the engineer of a boiler plant is by many considered no offence. But such a present, if accepted, would most certainly influence the results obtained in such practical trials of various fuels for the purpose of placing a large coal contract. Are not engineers a little too trustful of human nature in this matter, and would it not be advisable to have some counter-check upon the results of steam-raising trials of fuels under the boilers? The writer then recommends,—not that such practical trials should be dispensed with, but that a thoroughly reliable sample of the fuel used for each steam-raising test should be submitted to chemical and calorific examination, and that the results obtained in the trials under the boilers should be judged in the light of these laboratory results. If striking discrepancies should be revealed, the practical trials could be repeated with other men in charge.

The unreliability of the results obtained in many of the so-called "practical" steam raising trials is proved by the following extracts from one of the recent reports to the Manchester Steam

Users' Association by Mr. C. E. Stromeyer, its chief engineer:—

"On examining the trials summarised in the late Mr. Bryan Donkin's work on the 'Heat Efficiency of Steam Boilers,' it was found that whereas the results obtained by different experimenters on one boiler installation agree fairly well, the results obtained at other installations of exactly the same type of boiler are most erratic and even conflicting.

"Thus, if we confine ourselves to Lancashire boilers, of which about 150 tests are recorded, we find enormous variations in the efficiency of boilers worked under practically identical conditions. For instance, in two cases of hand-fired Lancashire boilers, No. 7 and No. 57 in Mr. B. Donkin's book, both burning English coal, the former at the rate of only 13.81 lbs. of coal per square foot of grate, against 16.5 in the latter case, and evaporating only 3 lbs. of water per square foot of surface, against 5.61 lbs., we yet find that the efficiency of the lightly-worked boiler No. 7 is only 53.7 per cent., against 71.6 per cent. in the case of No. 57, the hard-worked boiler. Again, comparing the two other tests, No. 12 and No. 67, we find the hard-worked boiler to be the more inefficient of the two, the performances being in the ratios of 53.2 and 74.8.

"Evidently these anomalies depended either on the experimenters, or on the conditions of firing. The recorded trials were, therefore, subjected to a careful analysis, and those in which the experimenters might be considered at fault, or in which their data were incomplete, were rejected. By this means the total number of about 340 boilers of customary types was reduced to a very few, more especially as, when making calculations, it was found that the data must have been incorrect, some boilers appearing to have received heat from outside instead of losing some by radiation."

The writer would recommend, for practical purposes, the "approximate" rather than the "elementary" analysis of fuels. The former gives the percentage of moisture, coke, volatile matters, fixed carbon, and ash. The latter yields the percentage of the various elements which are contained in the fuel, namely, oxygen, hydrogen, nitrogen and carbon. For the guidance of the boiler engineer, it is much more useful to know that a fuel contains, say, 29 per cent. of volatile hydrocarbons, 13 per cent. ash, and 58 per cent. fixed carbon, than to be informed that it contains 72 per cent. *C*, 4.8 per cent. *H*, 7.2 per cent. *O*, and 0.71 per cent. *N*.

Recently a formula was published by Goutel which permits the calorific value to be calculated from the results obtained by this "approximate" analysis; and, therefore, one of the arguments for carrying out the troublesome and expensive elementary analysis of fuel,—namely, that it enabled one to calculate calorific values with accuracy,—has lost weight.

In the writer's opinion, such approximate analyses of fuel ought always to be made in conjunction with practical steam-raising trials, and in the decision as to the choice of fuel, the laboratory results ought to have due weight. A further advantage of having the exact figures of the laboratory trials of the fuel for reference is, that a check upon the deliveries of fuel during the time for which the contract is running can be easily kept. At weekly, fortnightly or monthly intervals reliable samples of the fuel should be taken and submitted to the approximate analysis and laboratory calorimetric tests.

Any variation in the quality of the fuel should at once be reported, and the fact that such examination of their deliveries at the boilers was being periodically made would have undoubted effect upon the firm fulfilling the fuel contract and upon the colliery managers. It is not generally recognised that one colliery often supplies five or six varieties and qualities of coal from the different seams worked, with ash contents varying from 6 per cent. up to 20 per cent. The writer knows one such example.

At times accidentally, and at times possibly intentionally, buyers may be provided with a fuel much inferior to that for which they had contracted. Unless the fireman complains, nothing

is known or said about this deterioration; and, as already remarked, the fireman may have some interest in keeping quiet.

Coal-seams also become worked out in time, and such an incident may occur during the delivery of a contract. Hence the importance of instituting some scientific and systematic check upon the quality of the fuel deliveries.

It may be urged that periodic steam-raising trials are sufficient. But apart from the unreliability already referred to, of the results obtained in such trials, as guides to the quality of the fuel actually being delivered, there is the question of trouble and expense involved in conducting them. On the ground of expense alone the laboratory examination of carefully taken samples is to be preferred.

The chemical examination of fuel is regularly carried out in the laboratories of most railway companies and of large industrial establishments, and engineers of important steam plants everywhere would be wise to follow the same plan. If their consumption is not large enough to warrant the engagement of an analytical chemist and the equipment of a laboratory for this work, they might with advantage send their samples of fuel to one of the numerous chemists who specialise in this class of work. The analysis of fuel and the determination of its calorific value are not work of a very simple character, and the writer does not recommend engineers to attempt it themselves.

Even in the matter of sampling, much care and attention are required if the weight of fuel to be sampled is large and the sample is to be a thoroughly representative one. The notion of many engineers that a shovelful of fuel, selected hap-hazard and placed in a box, is a sample, is a most misleading one.

WATER SUPPLY

Most engineers are now ready to recognise the value of analyses of boiler waters. It is, therefore, not necessary to discuss this point at any great length. Where the hardness of the water used for feeding the boilers is above 15 English degrees, equivalent, that is, to 15 grains of calcium carbonate per gallon of water, some form of water-softening apparatus ought to be used. It is indeed questionable whether such an installation would not also prove remunerative in large power stations even when the water employed is above this standard of purity.

Lime and carbonate of soda or caustic soda are the usual chemicals used for water-softening. The amount of these which it is necessary to employ can be determined only by chemical examination of the feed-water. It is customary to base this calculation upon the results of one analysis only; but the examination should be repeated at quarterly or shorter intervals, for the character of the water supply may change, and the appearance of a water is no guide to its chemical constituents.

Calcium carbonate and sulphate, and the corresponding magnesium salts, are all held in solution in water, and may increase greatly in amount, without any change in the water visible to the eye. Water drawn from brooks or rivers in the vicinity of the coast may also at the times of flood or spring-tide become contaminated with much ordinary salt, which should not be permitted to collect in any large amount inside boilers, since it leads to pitting and corrosion. Here, again, no change in the water can be detected by the eye, and only chemical analysis will reveal the presence of this impurity in excessive amount.

THE COMBUSTION OF THE FUEL

Coal may, for practical purposes, be regarded as a mixture of solid carbon and volatile hydrocarbons, with moisture and ash as impurities. Engineers have not sufficiently recognised the combustion difficulties due to the high percentage of volatile matters present in many fuels, or the need for large combustion chambers to obtain perfect combustion in such cases.

The perfect and economic combustion of bituminous coal demands conditions which are not often met with in the

modern boiler plant. These conditions are:—

1.—A sufficiency of air, but not an excess.

2.—A sufficiently high temperature in the combustion chamber.

3.—A perfect mixture of the air and volatile hydrocarbons.

The first and second of these conditions are not always fulfilled in the ordinary working of boilers. The third condition is seldom recognised as essential, and where it is attained it is more the result of chance than of design.

The supply of air to the boiler furnace is, of course, controlled by the fireman; and the tendency, where no chemical examination of the flue gases is made, especially in large towns, is to work boiler fires with a large excess, as it is more easy to get over the smoke difficulty in this way. But excess of air means waste of heat in the chimney gases, since every pound of these gases carries off a definite amount of heat from the furnace, and the use of economisers does not entirely obviate this loss. With the exit gases at a temperature of 600 Fahr., the losses due to excess air may vary from 13 to 68 per cent. of the fuel burned. The latter loss is that represented by only 3 per cent. of carbonic acid in the waste gases, and is, of course, exceptional. But the writer has many times found only 7 to 8 per cent. of carbonic acid in the waste gases from modern boiler plants, and this shows a fuel loss of about 25 per cent.

With careful firing and correct draught an average of 14 per cent. of carbonic acid should be present in the chimney gases. The ordinary percentage is far below this figure, and some authorities place the general average at only 8 per cent. This low percentage is due to excessive draught and consequent unnecessary amount of air passing through the boiler flues. The result is a large increase in the amount of heat carried away by the waste gases. The actual loss, represented by the difference between 14 per cent. and 8 per cent. of carbonic acid in the waste gases, with chimney gases at 560 degrees Fahr., is equal to 10 per cent. of the fuel burned in the boilers.

As regards working boiler furnaces with too little air, and thus producing carbonic oxide in place of carbonic acid, with consequent loss of heating effect, —this danger is minimised by the fact that, with the cheaper forms of fuel, smoke is always produced when the air supply is insufficient, and the fireman has thus a visible check upon his work.

It would, however, be of advantage if engineers in charge of boiler plants would always arrange it so that firemen could see the chimney top without going outside the boiler house. When the plan of building construction is such that a direct view of the chimney is obstructed, reflecting mirrors can be used at one or two points to attain the desired end. Dampers that are in good working order, and that can be opened or closed by the fireman without leaving the firing plate of the boiler, are also essential adjuncts for the proper regulation of the air supply, for with bituminous fuels the amount of air required for perfect combustion varies greatly at the different stages of the process. An enormous volume of gas is liberated within the furnace of a boiler within a few minutes of firing when fresh fuel of this character is charged on to the red-hot layer of coke lying upon the grate bars.

A new instrument for registering the draught in the furnace, and before the damper, called the pyrimeter, has been placed on the market, and it is possible that the use of this by boiler engineers would also conduce to more efficient regulation of the air supply to the boiler fires. The instrument resembles an ordinary steam pressure gauge in appearance, and an intelligent fireman would soon learn how to use it with advantage. Rule-of-thumb methods in the matter of air supply to boiler fires should certainly be displaced. The problem when burning bituminous fuels is much less simple than the ordinary fireman realises; and, as already pointed out, fuel losses that can rise to 15 or 20 per cent. may result from this one cause alone.

As regards the second condition of

perfect combustion, namely, the maintenance of a sufficiently high temperature in the combustion chamber, this is absolutely essential in the burning of fuels containing 10 per cent. or more of volatile hydrocarbons, and it may be ignored only when using coke or anthracite fuels. Unfortunately, boiler engineers have not generally recognised this condition in the construction or setting of boilers, and nine-tenths of the factory smoke produced may be ascribed to the failure to maintain proper furnace temperature. The water-tube boiler makers are the chief offenders in this respect. In most of their boilers, as at present constructed and set, perfect combustion of the fuel can be obtained only when using anthracite coal. When ordinary bituminous fuels are used in such boilers, the volatile hydrocarbons which distill from the grate, even when mixed with a sufficiency of air, are brought too quickly into contact with the boiler tubes, and the temperature of the gases is thus greatly reduced before perfect combustion has had time to take place.

It is not sufficient to have a mixture of the inflammable gases and air for perfect combustion to ensue. These gases must not only be mixed, but they must also be maintained at or above a temperature known as the combustion temperature. This temperature for the hydrocarbons distilled from coal is given by different observers as between about 940 and 1200 degrees Fahr. The obvious method of obtaining this temperature is to provide a combustion chamber lined with some refractory and non-conducting material which will not allow heat to be dissipated before perfect combustion of the gases has occurred. Badly designed boilers may be made suitable for burning bituminous fuels without any very great capital outlay, and good results have been obtained with such modified forms of setting.

It may here be pointed out, too, that the evaporative efficiency of a boiler is increased by obtaining the highest possible initial temperature in the combustion process. According to Mr. Stromeyer, the heat transmission between the water and the hot gases is directly proportional to the difference of temperature between them, and, therefore, this transmission is higher the greater this difference. In connection with stationary boilers no serious attempt has yet been made to increase the temperature of the combustion process by heating the air used in the boiler furnace, but some progress has been made in this direction in the design of marine boilers.

When one notes the remarkable results and high thermal efficiencies obtained with the regenerative principle applied to glass furnaces, one is tempted to ask whether some of the heat permitted to escape with the waste gases from stationary boiler plants could not be utilised in this way, and the writer is of the opinion that this subject is well worth attention.

Turning now to the third condition for perfect combustion, namely, perfect mixture of the air and volatile hydrocarbons, we find the condition is imperfectly provided for in the ordinary boiler furnace when burning bituminous fuels. The mere opening by the fireman of the slide in the furnace doors will neither provide the amount of air nor the admixture requisite for burning the great volume of volatile hydrocarbons given off immediately after charging fresh fuel. Nevertheless, this is the only provision made in the ordinary types of boiler furnace.

A supply of air, preferably heated, coming in behind the bridge or at the rear of the fire-grate is also necessary in order to obtain perfect combustion, and this air must be distributed over the width of the furnace in order to provide all portions of the mass of volatile hydrocarbons with the oxygen necessary for their thorough combustion. A secondary combustion chamber, walled with non-conducting material, is also necessary, in order to guard against loss of temperature, before the combustion of these volatile gases is completed. The higher the percentage of volatile hydrocarbons in the fuel, the larger will be the space required for the perfect mixture and combustion of these products. Neglect to provide for the com-

bustion of these volatile hydrocarbons has led to the invention of a number of smoke prevention appliances (some good and some bad), which would have been utterly uncalled for had a little more knowledge of chemical science been included in the education of boiler engineers.

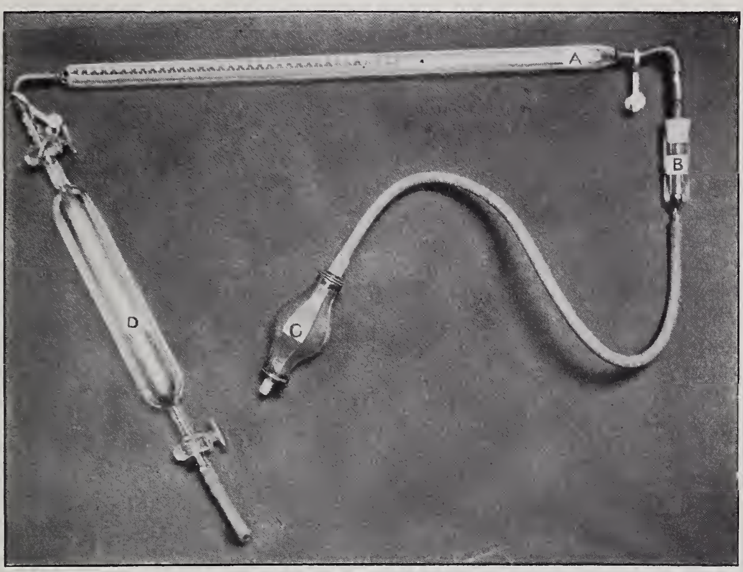


FIG. I.—FLUE GAS SAMPLING APPARATUS

THE WASTE GASES OF COMBUSTION

From what has already been said, it will be gathered that the regular and systematic examination of the waste gases from boiler furnaces is absolutely necessary for the attainment of the highest possible efficiency with the fuel used. Such examination should include the temperature of the exit gases; the draught behind the dampers; and the chemical constituents of the gases. At present, the plants where such systematic examination is carried out are comparatively rare.

As regards the temperature determinations, these may be made either with electrical resistance pyrometers of the Chatelier type, or with special high-temperature mercury thermometers, reading up to over 1000 degrees Fahr. These thermometers are made of glass of special quality, and are filled with nitrogen, under pressure, above the mercury.

A recording form of resistance pyrometer has also been placed on the market, affording a continuous record of the temperature of the exit flue gases, with little or no expenditure of time on the part of the engineer in charge. For works use a water pyrometer also is of some advantage, more especially for determining roughly the temperatures in places where a mercury thermometer could not be safely employed, or for determining temperatures much above the limit permissible with such a thermometer.

A simple form of water pyrometer consists of a small block of iron held in some suitable form of carrier by which it can be suspended in the flue where the temperature is to be ascertained. When the iron block has been exposed long enough to make it reasonably certain that it has acquired the flue temperature, it is immersed in a known weight of water of a certain temperature in a special receptacle, and the increase in temperature of the water is noted. With the weights of the iron block and

of the water receptacle known, and the other data just mentioned at hand, the temperature of the iron block, or, in other words, the temperature of the flue gases, can be easily calculated.

For the measurement of the draught,

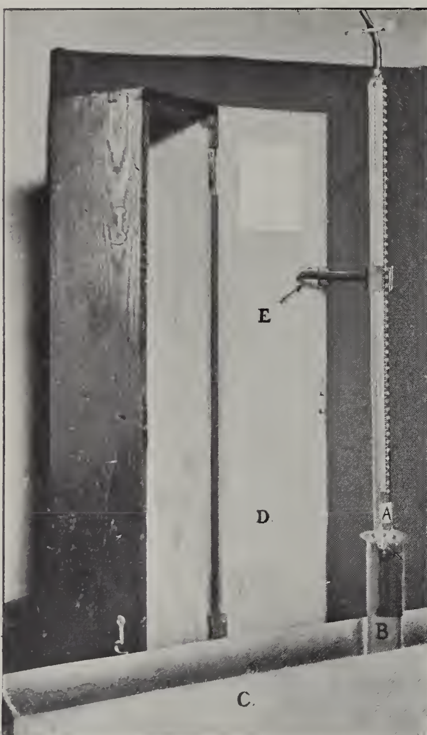


FIG. 2.—A CARBONIC ACID TESTING APPARATUS FOR WORKS USE

an ordinary water-gauge may be used, or the instrument known as the pyrimeter, already referred to, may be employed. Many failures to obtain perfect combustion in boiler furnaces are due to insufficient draught.

The chemical constitution of the exit flue gases may be ascertained with various forms of apparatus; but none of these will yield valuable results unless considerable thought, care, and attention are given to the sampling of the gases. An opening for drawing samples ought to be left at the time of setting, in the top or side flue-walls of each boiler, at the point where the boiler exit flue joins the main flue to the chimney. A 30-inch length of wrought-iron pipe, about $1\frac{3}{4}$ inches in diameter, with a flanged top, should be set with fire-clay in this hole, and cotton waste or an iron plug should be used to close the end opening to the air. When a sample of flue gases is required, such a sampling hole is always ready for use, and valuable time is not wasted in looking for the place or in clearing the accumulated rubbish from the hole when found.

The use of a large aspirator containing water cannot be recommended for collecting an average sample of gases over long periods, as carbonic acid gas is slightly soluble in water, and the absorption with a sample of gases, containing 8 per cent. or more of carbonic acid, is noticeable in a few hours. The author would recommend a series of snap samples taken at short intervals of time. The average test of these samples gives a reliable check upon the work of the boiler and fireman. The best apparatus for taking such snap samples is a rubber finger-pump, provided with a simple form of stop-valve for preventing any leakage of air past the valves of the pump, which are never perfectly tight.

Fig. 1 shows such a gas-sampling apparatus connected to two sample tubes. *C* is the rubber finger-pump, holding about 35 cc; *B* is the rubber stop-valve, which permits the gas to pass only from *A* to *C*; *A* is a Honigman gas-burette; and *D* is a gas-sample tube for preserving a check sample of the gas.

The sample of gas is obtained in these tubes by the dry method, five times the volume of gas being pumped through, by aid of *C*, so as to remove all the air originally present. For the apparatus shown, $5\ (220 + 100\ \text{cc}) = 1600\ \text{cc}$, is required, and 46 compression of *C* will effect this displacement of air and gas. A period of about two minutes will, therefore, suffice to obtain a reliable sample of the flue gases with this apparatus.

The sample of gas obtained in this way can be kept for many hours without suffering any change, since the amount of moisture which condenses on the interior walls of the glass sample

tube is not sufficient to absorb any material volume of carbonic acid. A sample tube provided with glass stop-cocks *D* must, however, be employed if the sample of gas is to be preserved some time before analysis. If it be examined at once, a tube closed with rubber and ordinary spring clips *A* may be employed with safety.

The complete examination of flue gases for carbonic acid, carbonic oxide, and oxygen is most conveniently carried out in the Orsat-Lunge form of gas-testing apparatus. Several forms of recording carbonic acid apparatus have also been invented and are in successful use. They yield valuable information, but require careful attention, and the results require checking by independent tests at intervals of three or four weeks.

For works use, the writer has designed a form of apparatus which he considers will yield valuable results in the hands of intelligent engineers in charge of boiler plants. This is illustrated in Fig. 2. *A* is a Honigman gas-burette, holding 100 cc; *B* is a cylindrical glass jar, 8 inches high and 2 inches in diameter; *C* is a zinc trough holding water; *E* is a spring-clamp; and *D* is the box which serves to contain all the apparatus when not being utilised as a burette stand, as shown in the illustration.

The gas to be tested for carbonic acid is collected by the dry method in *A*, and 100 cc are accurately measured, by removing the clip from the rubber at the lower end of *A*, fixing the burette in *E*, as shown, and adjusting the level of water in the jar *B*. Carbonic acid absorption is next effected by slipping into *A* by the wider end a small piece of solid caustic potash specially prepared for this use. The burette *A* is then removed from *E*, the end is closed with a glass rod, and the caustic potash is dissolved by gentle agitation. Two minutes suffice to dissolve the solid caustic and to absorb the carbonic acid in *A*, and after immersion of *A* in the water in the trough *C*, to bring the contents of the burette to the original temperature, the glass stopper is removed from the lower end of *A*, the burette is again fixed as shown in the illustration, and the reduction in gas volume is ascertained. This gives at once the percentage of carbonic acid in the original gas.

The absence of any liquid, and the compactness of the apparatus when dismounted and packed in its case, are two special points which should recommend it for works use.

WATER HOISTING INSTEAD OF PUMPING

IN THE PENNSYLVANIA ANTHRACITE REGION

By R. V. Norris, Chief Engineer of the Pennsylvania Railroad Coal Companies

Mr. Norris' article is a partial reprint of a paper read a short time ago before the American Institute of Mining Engineers, having been condensed for publication here. The half-tone reproductions of water hoists also were prepared specially for the present purpose.—THE EDITOR.

THE removal of mine-water by hoisting in tanks instead of pumping, while somewhat a reversion to the methods of the ancients, has come very rapidly into favour in the anthracite region of Pennsylvania during the past few years; in fact, so much so, that at the present time there are at least eight large collieries at which all the water is hoisted, and six more plants were in preparation during the past year.

The earliest regular hoisting, the writer believes, was done by means of semi-cylindrical tanks at the Nanticoke collieries of the Susquehanna Coal Company. These tanks were attached under the regular shaft-carriages, taking in water through six large clack-valves in the bottom, and discharging through an end-gate opened by a lever which was operated by a guide-piece on the shaft head-frame. These tanks were designed in 1880, by the late J. H. Bowden. Similar tanks are still used in emergencies at the Nos. 1, 2, 3 and 6 shafts of the company. The objections to their use were that water could be hoisted only during the night-shift, or when the shafts were not in use for hoisting coal, thus requiring a very large sump, and greatly limiting the water capacity of the plants; that the alternate wetting and drying of the shafts did considerable damage to the timber; and that the collection of ice in the main shafts, which are invariably down-takes for the ventilation, endangered the men in going up and down in their work.

These reasons, with the gradual increase of water beyond the capacity of the plant, led to the abandonment of this method of hoisting, so that now these tanks are used only in emergencies. The method was, however, probably one of the cheapest ever devised for handling a moderate amount of water from deep shafts, as practically the only cost was for the steam used, the extra wear and tear of engines, ropes, shaft-guides and timbering, and the extra oil required for lubrication. The hoisting engineers being required by the Pennsylvania mine law to be in the engine houses at all times, and night firemen being necessary at all colliery plants, there is really no additional labour cost to this method of hoisting. These tanks have a capacity of 1300 gallons (174 cubic feet) each, and 50 per hour was an ordinary dump, so that the total capacity, from a shaft 1000 feet deep, was about 750,000 gallons (8700 cubic feet) per day of twelve hours.

The present method of hoisting from a special water shaft or water compartment was, I believe, first used in 1896, at the Luke Fidler colliery, Shamokin, by Mr. Morris Williams, then superintendent of the Mineral Railroad & Mining Company, of which Mr. Irving A.

FIG. 1.—ONE OF THE ORIGINAL SQUARE TANKS AT THE LUKE FIDLER COLLIERY

Stearns was the manager. The plan was the outcome of the successful use of tanks in unwatering the colliery, which had been flooded to subdue a mine fire.

The tanks were made to dump as shown in Fig. 2, and, to get the maximum size, were made square with angle-iron corners; it was found almost impossible to keep them tight, and round tanks have been substituted.

The original method of dumping was the use of small wheels bearing against the guides to retain the tanks in a vertical position while hoisting; these passed through slots in the guides when the main dumping wheels reached the dumping rails (Fig. 2). These small wheels, if made of iron, rapidly destroyed the guides, and if of softer material, lasted for only a few hoists. The

present method of handling these dumping tanks is the use of a third guide (Figs. 2 and 3) at right angles to the main guides, and providing the tank (Fig. 4) with an extra shoe, set so as to give the tank a slight tilt toward the third guide; this shoe slides on the guide, keeps the tank steady and in a vertical position until the dumping wheels, near the top of the tank, engage the dumping rail at the top of the shaft, when the tank turns gently, pouring its contents into the discharge basin. Another great advantage of the third guide is the steadiness it imparts to the tank and the smaller liability to accident from shaking the guides loose.

The original tanks were provided with a single, large, flat, clack-valve at the bottom, which, in dumping, tended to swing to a vertical position and allow a small escape of water through it; this also struck the water very heavily in descending. The latest tanks are constructed with butterfly valves, set at a 45-degree angle, which entirely obviates the loss in dumping, and enters the water as a wedge with a much less severe shock (Figs. 4, 10, 11, 13 and 14).

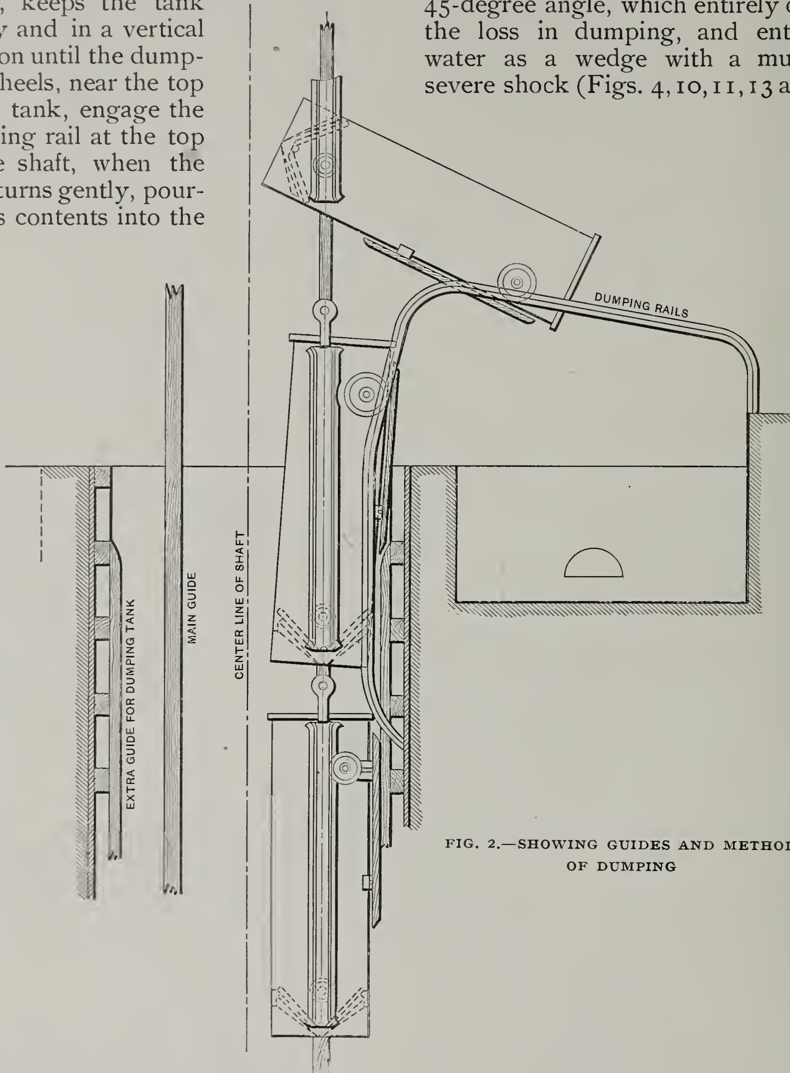


FIG. 2.—SHOWING GUIDES AND METHOD OF DUMPING

To successfully operate these dumping tanks, it is essential to arrange a rest in the sump on which the descending tank is supported while the upper tank is dumping. Without this the lower tank and rope may overbalance

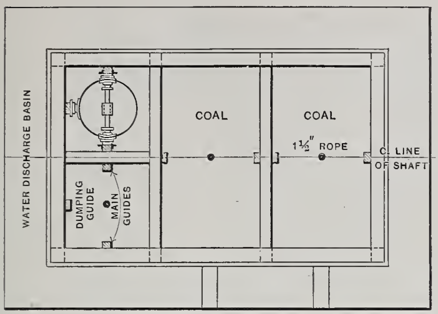


FIG. 3.—PLAN OF THE WILLIAM PENN SHAFT OF THE SUSQUEHANNA COAL CO., SHOWING A 1,440-GALLON TANK, TIMBER AND GUIDES

the upper tank, with nearly half its weight supported on the dumping track, and raise it sufficiently to reverse it in the shaft, and possibly do damage to the sheave.

The sudden reduction of load by discharging the water makes the landing a little delicate, and constitutes practically the only objection to this method of hoisting.

An automatic device is usually employed on shafts to minimise the danger from overwinds when hoisting water. The type used by the Philadelphia & Reading Coal & Iron Company and the Pennsylvania Railroad Company is known as the Kohlbraker & Williams overwinding device. It consists (Fig. 6) essentially of cut-off valves *G* close to the engine cylinders, and a trip-lever *A B C* in the shaft operated by the cage or tank, which, when struck, drops the weighted arm *E*, and by the movement of the lever *D* instantly cuts off the steam at the cylinders by the closing of the valves *G*, which applies the brake through the arm *H*. This will absolutely prevent damage from overwinding by starting the engine in the wrong direction or miscalculating the landing, and will minimise the damage caused by a runaway overwind, which, with the enormous weights and high speeds involved, could not be stopped short by anything less than the absolute wrecking of the engine. The damage from two such overwinds has recently been reduced to the wreck of the sheave and tank, and was accomplished by the use of a head-frame of the type shown in Fig. 8, in connection with the overwinding device. This type of frame gives a clear-through opening, with only the sheave in the line of the hoist.

As the usual dimensions of shaft compartments are about 7 × 13 feet, it is the general custom to use only one compartment for water hoisting (Fig. 3). This compartment is divided into two

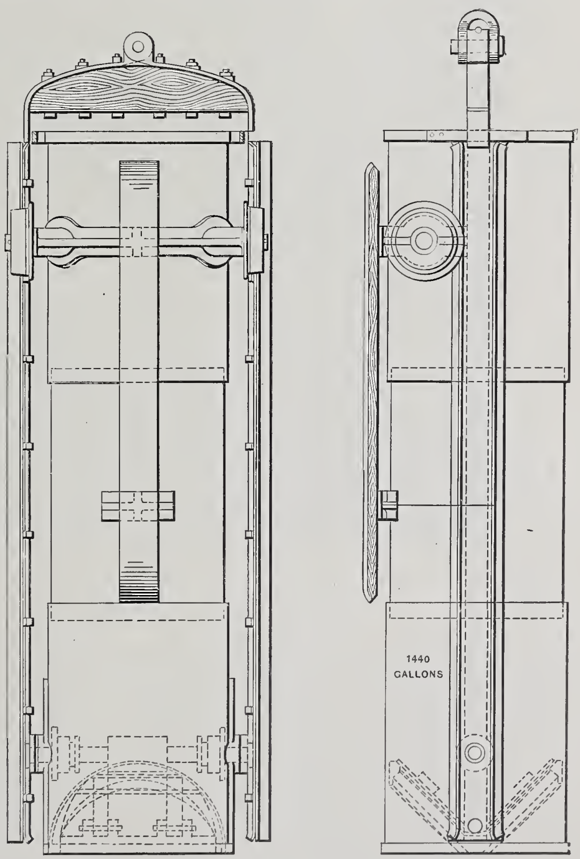


FIG. 4.—WATER-HOIST DUMPING-TANK OF THE WILLIAM PENN COLLIERY

FIG. 5.—A BOTTOM-DUMP TANK DISCHARGING AT THE LYTLE COLLIERY

parts by an extra line of buntins (when discharging at the end of the shaft), or two sets of guides are put on the sides of the compartment, with the extra guides on the ends when dumping at the sides of the shaft. The arrangement of two tanks in one compartment also reduces to a minimum the extra size and cost of shaft required for water hoisting. The water-hoisting engines are then usually set at right angles to the coal engines, to avoid placing one sheave over the other, with the resulting extra liability to wrecks.

Bottom-dump tanks, instead of end-dumping ones, are exclusively used by the Philadelphia & Reading Coal & Iron Company, and also by our companies, as emergency hoists in the coal compartments. These are generally constructed (Fig. 7) with the intake valve at the bottom, and are provided

with a trip lever, operated by a guide in the head-frame, to raise this valve at the top, and a discharge casting to direct the outflowing water to one side into basins or troughs. The various types of discharge castings and valves in use are shown in Figs. 10, 11, 13 and 14; in these it will be noticed that an effort has been made to reduce the blow incident to striking the water by the use of wedge-shaped castings; the Lytle Coal Company, by the use of a wedge-shaped sheet-iron shield, outside of the discharge casting, reduce the shock still more.

The objections to this type of tank are its unsteadiness in hoisting at high speed; slower discharge through the bottom valve (the experience at William Penn colliery having shown an advantage of 10.1 per cent. in favour of the end dump), and, greatest of all, the danger of damage to the guides caused by the slanting nose striking the water and the consequent side pressure on the tank, which is intensified by the reaction of the water entering on one side only. In the writer's experience with both types there has been practical immunity from trouble with the guides from the end-dump hoists, and almost constant difficulty with them when the bottom-dump tanks are used. One guide at the water-level, forced out after thirty days' service, was cut into fully 1½ inches by the wear of the tank guides; the cast bottoms are also more liable to breakage from striking obstructions or floating timber than are the wrought-iron tanks, the cast valve seats of which can be made heavy enough to withstand any ordinary battering without unduly increasing the weight of the tanks.

The discharge casting (Fig. 14) is designed to minimise these difficulties; the idea was suggested to the writer by Mr. George Hill, constructing electrical engineer for the Delaware, Lackawanna & Western Railroad Company. The plan is to make an open casting, which is a perfect wedge provided with a central partition, to take water in on both sides, and thus entirely avoid the side thrust due to the slanting bottom and one-sided entry of the water. In discharging, either arrangement may be made for taking care of the double discharge; or, where this is undesirable, only one valve may be opened, making the discharge in all other respects similar to that at present used. To compensate for the disadvantages above mentioned, the bottom-

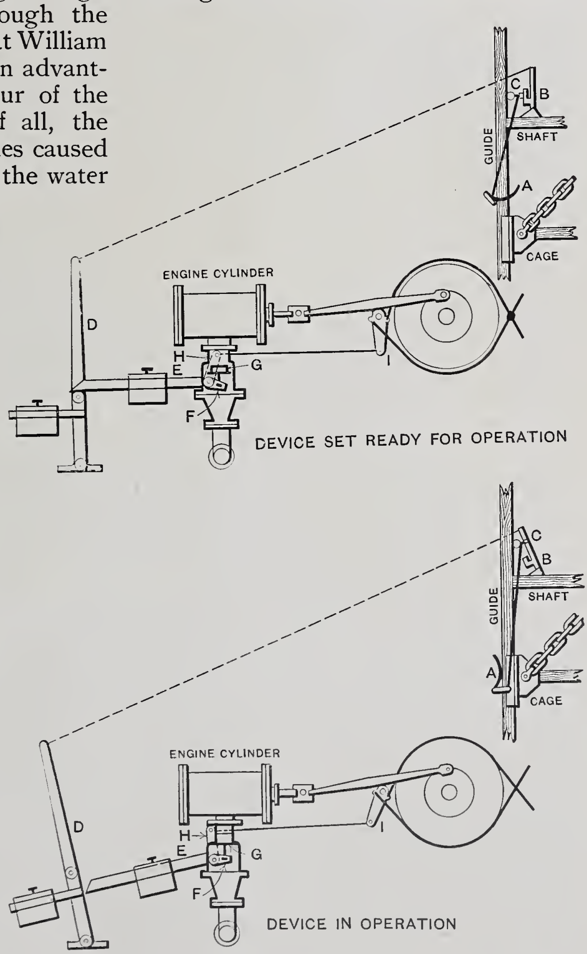


FIG. 6.—AUTOMATIC OVERWINDING DEVICE FOR HOISTING ENGINES

dump tanks do not require any special shaft or dumping preparation; the costly complication of mounting them on trun-

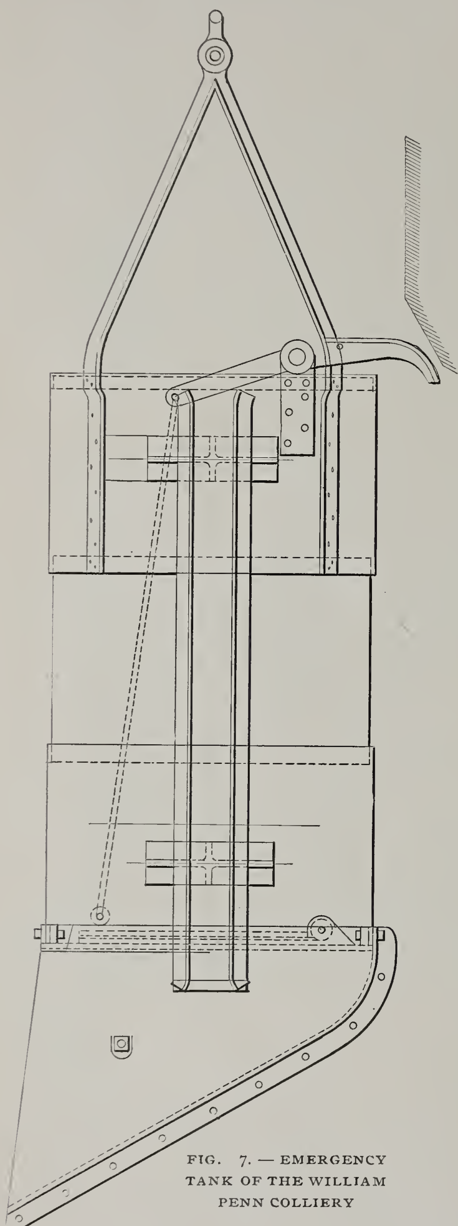


FIG. 7. — EMERGENCY TANK OF THE WILLIAM PENN COLLIERY

nions with a through shaft and stuffing-boxes is avoided; and the difficulty of landing, due to the sudden change of load, as before mentioned, is much reduced.

The time required for emptying bottom-dump tanks averages about eight seconds, while the actual stop for end dumps is but about two seconds, though some of this advantage is lost by the necessarily slower landing of the latter.

While all the regular water hoists are in shafts, very large quantities of water have been hoisted from slopes in emergencies. The tanks are usually of the end-dump type, and have done excellent work. The principal objections to their regular employment are,—the rapid wear of the wheels caused by acid mine-water working into the bearings and replacing the oil; the slower hoisting speed necessary for tanks running on wheels, as compared with those in shafts sliding on guides; the liability to derailment at any point of the hoist; the extreme danger of derailment when entering the water; and the danger, on flat slopes, of obstructions remaining on the rails under water.

There is, however, at the Hickory Ridge colliery of the Union Coal Company, Shamokin, a permanent water hoist on a 70-degree slope (Fig. 12), in which it is believed that many of these difficulties have been obviated. The tanks have a capacity of 1400 gallons each, and are mounted on closed, self-oiling wheels with bronze bushings, and close-fitting bronze shields in the end of the hubs, which fit over bronze collars on the axles. The wheels are made with extra high flanges, and the tank is provided with top and side shoes, as shown, which slide in between permanent guides, at the foot of the slope, extending 20 feet above the water-line, to avoid danger of derailment when striking the water; the pitch being 70 degrees, there will be no danger of obstructions remaining on the rails under water.

The summary of the operating costs of three water hoisting plants for which data were compiled by the writer shows that the cost of hoisting the water is much less than the average cost of pumping it as determined at the collieries of the Lykens Valley Coal Company, being $61.86 per horse-power-year, 24 hours per day, in the case of the hoist-

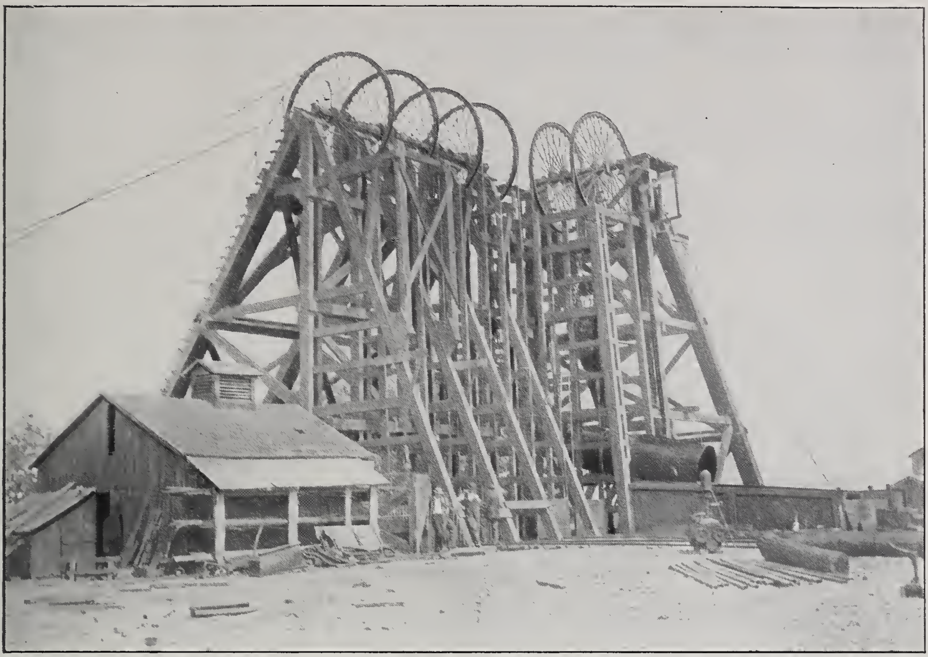


FIG. 8.—HEAD FRAME AT THE LYTLE COLLIERY

FIG. 9.—A 2600-GALLON TANK DISCHARGING

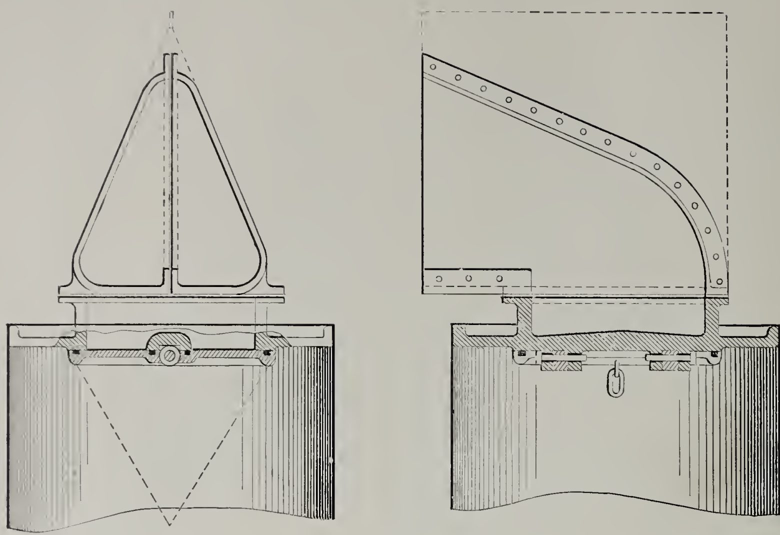


FIG. 10.—THE LYTLE COAL COMPANY'S BOTTOM-DISCHARGE TANK

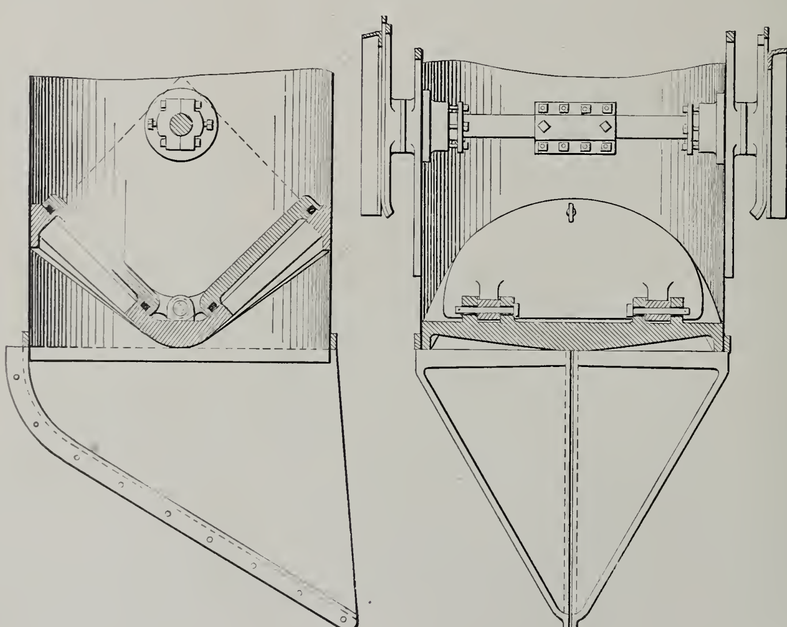


FIG. 11.—THE SUSQUEHANNA COAL COMPANY'S TANK WITH BOTTOM DISCHARGE CASTING. THE SAME TANK IS ALSO USED FOR TOP-DISCHARGE, WITHOUT THIS CASTING

ing plants and $89.79 per horse-power-year in the case of the pumping plants. In both cases, however, the steam costs could, if desired, be reduced by the use of compound engines, condensing or non-condensing, or even by running the present simple engines condensing.

Aside from the question of cost, however, there are many very great advantages in hoisting water, particularly from deep shafts:—(1) in the simplicity of the construction; (2) having all the operating machinery on the surface, with the resulting low cost of repairs, which are practically confined to tanks and ropes; (3) the almost total absence of slip, which under mining conditions reduces materially, from the quantity calculated from "plunger displacement," the actual quantity of water pumped; (4) the avoidance of underground steam lines, with their large condensation losses, damage to roof and timbering from the heat and exhaust steam, and the danger of fire incident to their use; (5) the almost total freedom from danger of falls or squeezes in the mines; and (6), most of all, because the operating plant cannot be flooded.

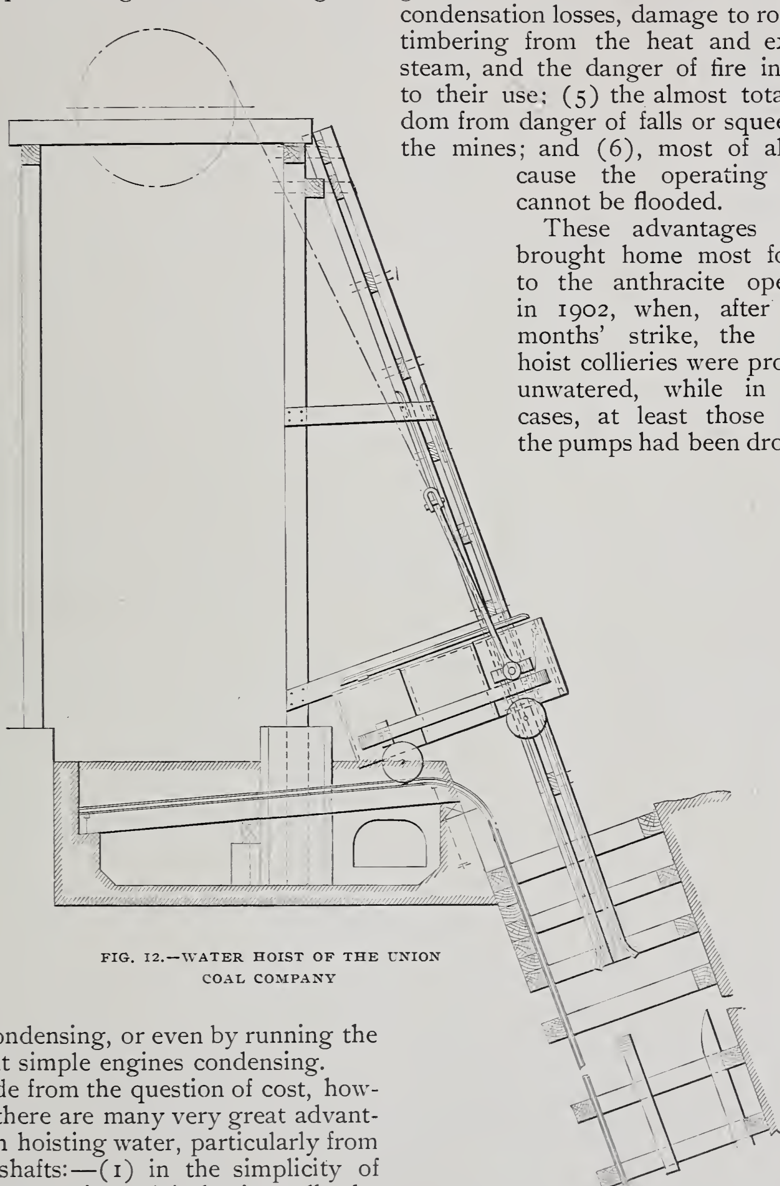


FIG. 12.—WATER HOIST OF THE UNION COAL COMPANY

These advantages were brought home most forcibly to the anthracite operators in 1902, when, after a six months' strike, the water-hoist collieries were promptly unwatered, while in other cases, at least those where the pumps had been drowned, the mines remained flooded in the lower levels for varying periods. The history of the Lytle colliery, a notoriously wet one, also furnishes a

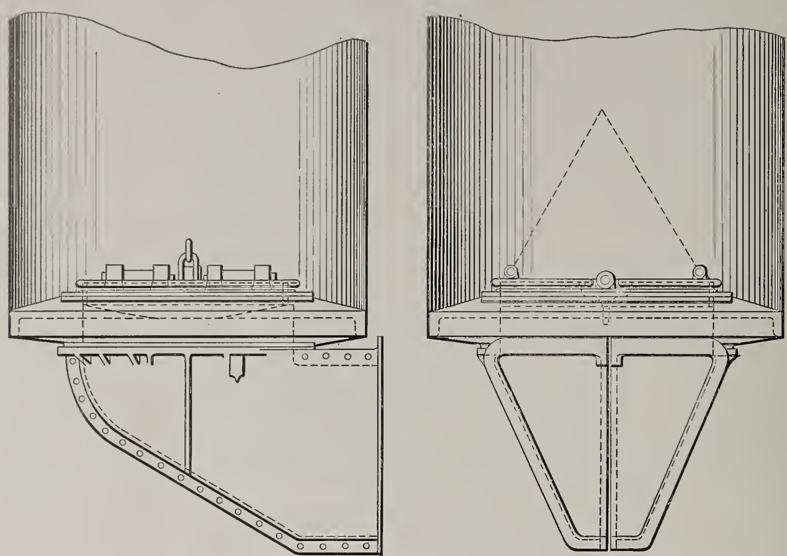


FIG. 13.—THE PHILADELPHIA & READING COAL & IRON COMPANY'S BOTTOM-DISCHARGE TANK

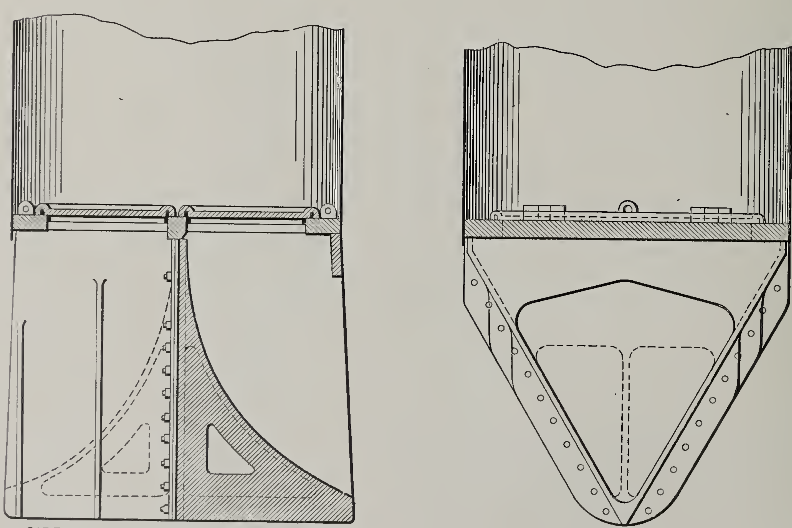


FIG. 14.--THE SUSQUEHANNA COAL COMPANY'S TANK WITH DOUBLE BOTTOM-DISCHARGE CASTING

case in point. Until the accession of the present management, the regular report was, "we are holding the water," and it required seven months of unremitting effort moving pumps down the slopes, and a tremendous expenditure of money, to clear the colliery of a volume of water barely equal to that removed by the hoisting plant in one instance in thirty-seven days.

MODERN GAS LIGHTING

ITS ADVANTAGES OVER THE ELECTRIC LIGHT

By W. H. Booth

UNTIL within comparatively recent years almost all gas lighting was effected through the medium of the flat-flame burner. Light was given by burning coal gas. The light emanated from incandescent particles of solid carbon which were heated in the burning gas and gave out light themselves during the process of combustion. The particles of solid carbon in the flame were due to a decomposition of certain constituents of the gas.

Coal gas is a complex mixture of many hydrocarbon gases, ranging from marsh gas, or light carburretted hydrogen or CH_4, as usually written by chemists, up to such heavy gases as benzine. It is to the heavy constituents, usually denominated the illuminating constituents, that light is due. These constituents are but a very small percentage of the total volume of coal gas. Other gas burners arose in time, such as the Argand, with its circular, hollow flame, fed with air both inside and out, induced by a chimney, and there were various other types of burners, fed with hot air on the regenerative system.

But these simply promoted a more brilliant incandescence of the solid carbon in the flame, and the basis of gas lighting was the decomposition of the richer hydrocarbon gases, the separation of the carbon in solid form, the raising of it to a high temperature, and, in order to prevent a nuisance, its final complete combustion. Yet this finally complete combustion was rarely attained, and gas lights always produced a considerable quantity of soot. It need scarcely be remarked that the incandescent light-giving particles of carbon in a gas flame are simply so much highly heated soot in process of combustion.

A little consideration will make it clear that a gas flame gave out light only because it was supplied with an insufficient amount of air for rapid and complete combustion. If air be mixed with coal gas a few inches in advance of the point of ignition, the hydrocarbon gases enter into combination with the air or oxygen without decomposition taking place. In the absence of sufficient air the hydrocarbon gases decompose. The hydrogen makes a first claim on the oxygen, and the carbon is left free and becomes incandescent in the hot flame of the hydrogen. At the edges of the flame the hot carbon obtains a further supply of air and becomes fully, or nearly fully, burned and non-luminous.

Lighting by coal gas, as recognised to-day, consisted in a maximum of heat and a minimum of light. Very little effect was secured from the calorific capacity of the gas, and it was the boast of the electric light men that gas, burned in the gas engine to generate power to drive a dynamo, would produce, despite the intermediate losses, a greater amount of light than could be obtained when the gas was burned in the ordinary manner.

For one hundred years, in fact, little or no improvement had been made in the methods of using gas, nor was it

looked upon as good policy to encourage systems of gas burning which made for economy. The standard of gas light was a paltry 16-candle power from a flame burning at the rate of 5 cubic feet of gas per hour. The modern system of gas lighting had been foreshadowed in the lime light, which consisted of a cylinder of lime, heated to incandescence by a jet of hydrogen or of hydrocarbon gas with oxygen. In the lime light it was the calorific capacity of the burning gas which produced the light effect. In place of so many minute particles of incandescent carbon in a flame of hydrogen, a highly heated mineral white surface was substituted.

To-day it is easy to trace the steps from the heated lime cylinder to the Welsbach mantle heated in the flame of the Bunsen burner. The Bunsen burner has, of course, been long known as a most efficient apparatus for burning coal gas so as to make use, to the full, of its calorific capacity. But it required the stimulus of the electric light to spur inventiveness in the direction of improved methods of gas lighting. The Welsbach burner, using 3 to 8 cubic feet of gas per hour, will give a light of eighteen candles per cubic foot, or sixfold the light given by the old types of burners.

Gas companies recognised, tardily it may be, that if electricity was to be faced successfully, there must be great improvement in gas lighting. Undoubtedly the worst neglect in the system of gas lighting has been that which allowed the products of combustion to escape into the atmosphere of our rooms in place of leading them away by suitable tubes to chimneys and thereby compelling gas lighting to become a useful and efficient ventilating agent. A gas-lighted room was unhealthy. Gas injured books and pictures and decorations, but this was inevitable where no care was taken to ventilate.

With the modern systems this damage is very much reduced in proportion to the amount of light produced. But the main point has been that gas now gave more light by far than could be obtained from electricity. While doing so, it also became possible to reduce the quality of the gas in respect of its illuminating power. With the mantle it mattered nothing that the gas was practically non-luminous under ordinary conditions. The mantle light did not depend for its properties upon the self-illuminating constituents of the gas burned. It was all a question of the calorific power of the gas, of its capacity to raise the temperature of the mantle to a sufficient degree of light, giving incandescence. Thus in mantle burners the chief power,—the calorific capacity,—of a gas has been beneficially employed where formerly it went to less than useless waste, and, as the calorific capacity was greater than the illuminating capacity, the economy of the mantle was great.

It was only natural that once the merits of the incandescent system had been recognised, further progress should be made. As in burning coal, so in burning gas it has been found that the more intense the combustion, the shorter will be the flame produced. In mantle burners, designed to burn 3 to 8 cubic feet of a certain gas per hour, any greater rate of combustion is productive of no better effect. The additional supply of gas burns to waste above the mantle. The length of the mantle must not be less than the height of the flame.

It is important also not merely to secure the usual Bunsen flame, but to secure intensity of temperature by getting that flame short. To secure a short flame, gas is supplied under higher pressure through smaller orifices, drawing in a fuller air supply. A shorter and hotter flame is the result, heating up a mantle to a more brilliant incandescence.

In incandescent gas lighting the flame must fit the mantle or *vice-versa* for best effect. Higher pressure may be employed with still better effects, but it is found that with a gas mixture of two-thirds air, the intensity of the flame is so great that mantles will not stand, and at high pressures only half the volume of air, or a ratio of 1 to 1 is employed. The present condition of gas lighting is such that the mantle bars the way to any further improvement; but with

better mantles there can be better efficiency.

At present with one of the current systems a thousand feet of gas, at three shillings per thousand feet, will produce 36,000 to 40,000 candle-hours, or 1000 to 1100 candle-hours for one penny; that is to say, fully 20 hours of 50 candle-power for one penny. Users of electricity may compare their bills on the basis of three lamps of 16 candle-power each, run for 21 hours, and they will perceive how exceedingly extravagant a light is that from electricity. If the energy in coal be calculated, it will be found how very small a proportion of that energy appears as power in the crankshaft of an engine, and with the best engines and dynamos there is but a mere fraction of the calorific power of the coal present in the electric current, and the conversion of this final fraction into light is still far removed from unity.

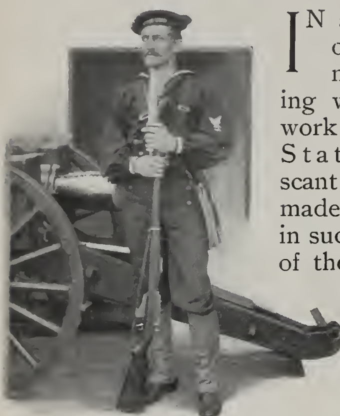
Gas lighting with modern methods is at present far ahead of electricity in all save convenience, and, under ordinary circumstances, health. The matter of health is not insurmountable. The economy in one year over electricity would pay for the ventilation necessary to remove the products of combustion. At this moment electric lighting stands where it did when first commercially introduced. There has been practically no progress. It is certain that there can be no such progress as will equalise the cost of the two lights so long as electric light depends on steam power for its prime mover. Gas engines will do something to reduce cost, but there can be very little doubt in the mind of any engineer that the plant required for producing the electric light is out of proportion extravagant as compared with that required for gas light.

Electricity lends itself to situations for which gas is out of the question; but for plain, straightforward lighting of rooms, workshops and public buildings it appears very doubtful whether electricity will continue to hold first place in any sense of the term. The machinery of electric light has become more complicated instead of simpler as time has moved on. Electric light engineers appear to have succumbed to this tendency without an effort, and their undertakings have been burdened with this load of complication as well as a load of duplicate plant made necessary by the hand-to-mouth methods which are still practically compulsory in the absence of a satisfactory system of electric storage.

In coal consumption the incandescent electric light probably demands three times as much as modern gas lighting. The hope for electric lighting seems at present to lie in the direction of the arc lamp. It has been said that gas at three shillings per 1000 cubic feet is equal to electricity at six pence per unit. This is with flat-flame burners. With the Welsbach light, gas at three shillings is equal to electricity at one penny per unit. With other gas systems the cost of electricity must come down to a still lower figure to bear favourable comparison, and this at present seems to be beyond the range of visible possibilities unless in the direction of flame arc lamps, which themselves appear to be outside the range of domestic lighting.

THE SCIENTIFIC WORK OF THE UNITED STATES NAVY

By Rear-Admiral C. M. Chester, U. S. N.



IN a recent article in one of the popular magazines,* dealing with the scientific work of the United States Government, scant reference has been made to the part taken in such work by officers of the Navy, although these have exercised a material influence on the specialties of several of the government departments besides their own. It seems proper, therefore, to here supply some of the deficiencies of that other publication.

A reference to it will show that under the Treasury Department of the United States Government the construction of buildings (Supervising Architect's Office), and the making of coin (Director of the Mint), and of light-houses (Light-House Board), are scientific in character; but as the Bureau of Construction is absent from the list of bureaus under the Department of the Navy, it would imply that the construction of modern ships of war is not scientific work. And yet, if the building of houses requires scientific skill, how should the design of warships be classified?

In planning the construction of ships, a proper proportion for each of the varying elements within the most minute limits of dimensions and displacement must be attained. The naval constructor must fix the relative weights between gun-power and armour protection. An invulnerable armour must not be made at the expense of either gun-power or speed. His design must include capacity for ammunition, coal and stores which will carry the ship through a protracted battle. There must be structural strength with corresponding weight, in order that the enormous stress due to the firing of a ship's battery *en masse* may not produce undue strain. Moreover, the aggregation of these different requirements is limited by the draught which it is practicable to carry into harbours at all stages of the tide.

The harmonising of all these varying interests demands the most comprehensive scientific skill of any engineering work. So thoroughly is this recognised that the United States, until recently, sent its graduates from the Naval Academy abroad for years of study in special fields to qualify them for these important duties.

Of the academy at Annapolis itself the late Dr. Robert H. Thurston, director of Sibley College, Cornell University, has said:—

"It is the most complete and perfect institution of its class, perhaps of any class, in the educational world which has ever been conceived." Yet its curriculum must be supplemented by further studies in order that its graduates may qualify as constructors.

Again, under the Department of War the Bureau of Engineering (Chief of Engineers), which has charge of the construction of fortifications and other engineering works, appears; but under the Department of the Navy the officer who has charge of the construction of machinery of men-of-war (the Bureau of Engineering) is marked by his absence. Will engineers admit that such

* "The Scientific Work of the Government." By Prof. S. P. Langley. *Scribner's Magazine*, January, 1904.

work as is done by this bureau is unscientific?

In an article in the *Popular Science Monthly* on Rear-Admiral George W. Melville, until recently engineer-in-chief of the United States Navy, Dr. Thurston has written:—

"In the details of his work the Chief of Bureau has always exhibited the most thorough familiarity with its scientific side, and his plans have always involved the employment of every expedient known to science for promotion of efficiency. He has advocated increased thermodynamic range, higher ratios of expansion and greater piston speeds for his engines to give increased thermodynamic efficiency; has made effective provision against those extra-thermodynamic wastes which constitute the most serious tax upon heat utilisation, and has adopted every sound system of improvement known to modern science as bearing upon his work. The existing fleet is, as a whole, the production of the engineers and naval architects and ordnance officers of our Navy Department."

The Bureau of Ordnance, which has under its charge the construction of guns, is, according to the first-mentioned article, a scientific bureau in the War Department, but under the Navy the writer does not so classify the work. The naval ordnance officers have not only the construction of guns to look after, but the important subject of armour-plating as well, which also calls for special scientific knowledge. Like ship construction, the design of naval guns is hampered by the conditions of space, weight, and control, and cannot be studied from the simple formulæ for strength. Consequently, the inevitable compromise to varying requirements enters the problem and demands the most delicate treatment.

The ordnance officers of the Navy have had a very material influence on the wonderful growth of the steel industries of the country, and the large steel manufacturers have drawn on the Navy for instructors in the scientific development of their plants. Such men as Lieutenant Meigs and the late Lieutenant C. A. Stone resigned from the Navy at the call of the Bethlehem and Carnegie companies to perform work of this nature. Can any unbiased mind doubt the scientific ability of the Navy's ordnance officers?

Under the Department of the Navy the bureau that has charge of the construction of enormous dry docks,—the Bureau of Yards and Docks,—which requires a consideration of almost every branch of science, and which also plans the other large engineering works at navy yards, is unscientific in the opinion of the writer of the first-mentioned article, or, at least, is of so little scientific value as to be unworthy of mention. Similar duties under the Treasury Department, but of a less technical character, are, however, credited to science.

The Bureau of Equipment in the Navy is another which is absent from the list, notwithstanding that it has charge of, and has designed, the electrical appliances of the Navy, which are of commanding importance in the management of modern warships. This bureau also has given the most advanced thought and practice to the wireless telegraph system, yet the officers who do this work are, inferentially, not scientific men.

These unscientific officers of the Bureau of Equipment have so built up the plans of numerous electrical appliances that are used in the Navy as to make their specifications standard, in many respects, for all such implements produced in the country. So noted has become their leadership in this line that when the electrical expositon at Buffalo was planned in 1901, the whole structure was practically built upon specifications emanating from naval officers.

Sprague, the father of the electric trolley system, was in his early manhood a product of this branch of the Navy's professional work, and learned his lesson in the same scientific school where all naval officers attached to this bureau are educated,—the United States Naval Academy.

Note the number of Naval Academy graduates high up in the council of the leading electrical companies of the country, and then say that naval officers

know nothing of scientific work as implied in the article under discussion.

This bureau has, moreover, the charge of the Hydrographic Office and the Naval Observatory (including its branch, the Nautical Almanac), which are admittedly scientific in character; but the bureau itself, according to the same view, is not a scientific bureau. It is suggested that even these institutions are permitted to enter the list only as the means to an end.

To be sure, the article under discussion refers to all the Navy bureau officers in general as representing "an aggregation of men making direct application of science to the needs of the government, not infrequently resulting in original contributions to knowledge." But what is claimed is that they do more than apply science to governmental requirements; they are investigators as well, and in many cases have been pioneers in many branches of science, as was contemplated in establishing the educational system for navy officers. Of course, the Coast and Geodetic Survey is mentioned as a scientific bureau, and, as stated, it "has now over one hundred field officers, and a fleet of twelve steamers and six sailing vessels, besides many launches and small craft." Its accomplishments are accounted in glowing colours, one of them being that it "has sounded minutely nearly 300,000 square miles of water and made deep-sea soundings over little less than a million square miles."

Is there anything in this article that would imply that any portion of this work has been done by the officers of the Navy? Let us refer to the records and see what has been done by them.

An Act of Congress passed in 1807 (February 10) is the first statutory decree on the subject of the Coast Survey, and reads:—

"The President is authorised to cause a survey to be taken of the coasts of the United States, in which shall be designated the islands and shoals, with the roads or places of anchorage, within twenty leagues of any part of the shores of the United States; and also the respective courses and distances between the principal capes or headlands, together with such other matters as may be deemed proper for completing an accurate chart of every part of the coasts within the extent aforesaid."

The same law authorised the President "to cause proper and intelligent persons to be employed, and also such of the public vessels in actual service as he may judge expedient."

Under this authority plans for carrying on the survey were called for, and Prof. F. R. Hassler, a native of Switzerland, having submitted one which was approved by the President, was, in August, 1811, sent abroad to purchase instruments. The disturbances due to the war between Great Britain and the United States caused numerous delays in the fulfillment of Hassler's instructions, and owing to his detention abroad as an alien, he did not return to the United States until 1815.

Nothing was done in the surveying line until 1816, when a small beginning was made near the harbour of New York. This work consisted in establishing two base lines, one of verification, and a small amount of triangulation. On April 14, 1818, Congress repealed so much of the third section of the Act of February 10, 1807, "as authorised the employment of other persons in the execution of said Act than the persons belonging to the Army and Navy." Hassler was thereby relieved from the survey, with little or no actual surveying to his credit, and before he could publish the results of his first year's work. His records were turned into the War Department for safe keeping, and remained there until the re-establishment of the Survey in 1832.

In the meantime, however, from 1816 to 1832, naval officers continued to survey detached portions of the coast without any special appropriations by Congress, as they have since done many times and in many places. On July 10, 1832, this service was recognised and Congress appropriated $4000 "for defraying the extra services and expenses of the officers of the Navy engaged in

the survey of our coasts and harbours the past and present years."

The experience and knowledge gained by the Navy during the progress of these surveys following so closely the war of 1812-15, in which naval vessels were at times put in jeopardy by the insufficiency of charts, led ambitious officers to persevere in the development of the dangerous coast line, in spite of the want of congressional legislation. In 1832 the Secretary of the Navy, Hon. S. L. Southard, having made a strong appeal for the means of continuing the surveys for the benefit of the then increasing Navy and commerce in general, Congress took action and appropriated $20,000 for carrying into effect the Act of February 10, 1807. It authorised the President to "employ all persons in the land or naval service of the United States, and such astronomers and other persons as he shall deem proper."

Hassler was again appointed superintendent on August 9, 1832; but before much work had been done the administration of the survey was, on March 12, 1834, put under the control of the Navy Department. It was apparent, however, that while the officers of the two military departments were engaged upon the survey, it could be more harmoniously administered under one of the civil departments, and a retransfer was effected and the Treasury Department again assumed control on March 25, 1836.

The Coast Survey was reorganised in 1843, and in the Act approved on March 3 of that year the President was required to "cause to be employed as many officers of the Army and Navy of the United States as will be compatible with the successful prosecution of the work."

This requirement was reiterated in the Act of June 14, 1844, as follows: —

"Officers of the Army and Navy shall, as far as practicable, be employed in the work of surveying the coast of the United States."

This arrangement continued until the breaking out of the Civil War, when Army and Navy officers were called into active military service, as were also many of the civilians attached to the Survey. Soon after the close of the war requisition was again made for their services, and the naval officers once more became the hydrographers of the Survey. Army officers were, however, not employed in the Coast Survey after the war.

Between the dates of the Civil War and the Spanish-American War of 1898 naval officers did practically all the hydrography of the Survey. The steamer *Blake*, under Howell, Sigsbee, Bartlett, Brownson and Pillsbury, who had associated with them for a portion of the time that eminent scientist, Alexander Agassiz, gained for the Survey its prestige abroad more than any other part of its force, and yet not one of these names has honourable mention even in the article which has prompted these remarks. The hydrographic work of the naval officers has enabled the superintendent to put on file this splendid record, and yet it is implied that it was executed by its "one hundred field officers" which the Survey has now.

From this record it appears that up to 1832 all the work of the Coast Survey, except the triangulation of New York harbour, consisted of hydrographic surveys made by naval officers. In fact, the organisation of the Survey, which began by the appointment of a superintendent in August, 1816, was hardly begun before it was disbanded by the Act of 1818, between which date and the date of its re-establishment in 1832 the Navy had practically the whole field to itself and executed all branches of the Survey.

In the period from 1823 to 1825 naval officers, appreciating the necessity for surveys, strove to establish a hydrographic corps modelled after the British naval system. The far-sighted officers of the Service, however, saw that while this would build up a scientific grade favouring a particular branch of the Navy's professional work, a more suitable plan would be to have all officers scientifically trained at a school such as had been established for the Army at West Point, New York, in 1803. Agitation in this direction eventually caused

the establishment of the United States Naval Academy, at Annapolis, Md., now the acknowledged peer of any scientific school in the world.

The wisdom of this policy is clear, and so pronounced have been the advantages of scientific training to our Service that the British Navy is now following our lead, having recently adopted practically the system of education of the United States Navy. Its navigational branch has been discarded, and all officers are required to prepare themselves for the important duties of command by studies in all branches of their profession.

But the survey of the coast lines of the United States and its possessions under the Coast and Geodetic Survey is not the only surveying work done by American naval officers, nor the summation of its scientific duties. Look at the charts published by the Hydrographic Office, showing work done outside the United States, including not only hydrography, but geodesy and topography as well! On these charts will be found such names as Dewey, Philip, Clark, later distinguished Admirals, and Belknap, Nichols, and others, "whose works shall live after them."

Nor did the naval interest in hydrography cease after it became absolutely necessary to detach every officer from the Coast and Geodetic Survey to help man the critically deficient fleet, for today we have five naval vessels engaged in surveying the Philippine Islands alone, a survey that is being carried on while the Navy watches the inhabitants and prepares for the eventuality of war around the thousands of miles of coast line. Another ship is surveying the Samoan Islands as well.

Without such aid as these surveys afford, which is incidental to the most onerous and unhealthy tasks ever allotted to a navy, no complete surveys of the Philippine Islands could be made within twenty-five years, and in the meantime the national treasury might be depleted by millions of dollars due to lost ships.

The first scientific expedition that ever left American shores, fitted out by national munificence, was that in command of Lieutenant Charles Wilkes, U. S. N. It consisted of a squadron of vessels, comprising the steamships *Vincennes*, *Peacock* and *Relief*, the brig *Porpoise*, and the tender-schooners *Sea-gull* and *Flying Fish*, sent to the Southern Ocean in 1838 for the purpose of promoting "the great interest of commerce and navigation." In addition to this, Wilkes' instructions required him to "take all occasions, not incompatible with the great purposes of your undertaking, to extend the bounds of science and promote the acquisition of knowledge."

Continuing, the orders read:—"The hydrography and geography of the various seas and countries you may visit in the route pointed out to you in the preceding instructions will occupy your special attention, and all the researches connected with them, as well as with astronomy, terrestrial magnetism, and meteorology, are confined exclusively to officers of the Navy, on whose zeal and talents the Department confidently relies for such results as will enable future navigators to pass over the track traversed by your vessels without fear and without danger." There were attached to the expedition one philologist, two naturalists, one conchologist, one mineralogist, one botanist, two draughtsmen, and one horticulturist (no astronomers, no magnetologist, no meteorologist).

This was one of the most notable expeditions ever fitted out by any country, particularly so for the period during which it worked, and it gave to the United States a vast amount of knowledge of the South Seas, including the islands of the Pacific and the Antarctic continent, finally ending in an extensive survey of the vast territory of the Pacific coast and the adjacent waters, from Alaska to the southern limits of California. The records of this important expedition are contained in seven quarto volumes, full of interesting and scientific information.

Again, in 1847, the Navy Department fitted out an expedition to explore the Dead Sea and the River Jordan, under the command of Lieutenant W. F.

Lynch, U. S. N. This expedition visited the inhospitable country of Palestine, where its military composition alone made it possible to overcome the many obstacles there encountered. Its staff brought back to America a vast amount of data relating to geography, geology, hydrography, ornithology, botany, palæontology, etc. Lynch's records were published in accordance with a resolution of the United States Senate, and have been standard for many years; but being only preliminary, they have naturally been amplified and expanded by others until they are now but little more than a relic of the past.

Still another surveying and exploring expedition which contributed to the general good of the country was that known as the Ringgold Expedition, under the command of the then Commander Cadwalader Ringgold, U. S. N., and when, owing to failing health, he was relieved, the late Rear-Admiral John Rodgers, then a commander in the Navy, took up the work and carried it to a successful conclusion. The following brief account is taken from Professor Nourse's "American Explorations in the Ice Zone":—

"The expedition consisted of the sloop-of-war *Vincennes*, the screw steamer *John Hancock*, the brig *Porpoise*, the schooner *J. Fenimore Cooper*, and the storeship *J. P. Kennedy*. The squadron sailed from Norfolk on June 11, 1853. The primary object of the expedition, laid down in the instructions of Secretary Kennedy, was the promotion of the great interests of commerce and navigation, special attention being also directed to the increasing importance of the whale fisheries in the neighbourhood of Behring Strait. The thorough examination of that great outlet was expected, as well as that of the adjacent coasts of North America and Asia, including the seas of Behring and Anadir and the Aleutian Archipelago, with the east coast of Kamchatka. He was instructed also to take all occasions not incompatible with these high objects for the extension of the boundaries of scientific research. Thus always following utilitarian purposes, science came in as an important factor in the requirements of all naval expeditions of this kind.

"How nobly the gallent men of the Navy struggled to contribute their share to the country's welfare can be inferred by the fact that one of the ships,—the brig *Porpoise*,—was lost with all hands on board, including, as the Secretary of the Navy stated, some of the best scientific young officers ever found in any country."

Secretary of the Navy Kennedy, then in office, took a deep interest in such expeditions as this, and in his annual report of December 2, 1852, he expressed his views as follows:—

"The constant employment of ships and men in the promotion of valuable public interests, whether in defence of the honour of our flag or exploration of the field of discovery and the opening of new channels of trade, or in the enlarging of the boundaries of science, will be recognised both by the government and the people as the true and proper vocation of the Navy, and as the means best calculated to nurse and strengthen the gallant devotion to duty which is so essential to the character of accomplished officers and so indispensable to the effectiveness of the naval organisation."

This is the key-note to all the Navy's aspirations, and one of its greatest glories is that during its comparatively short lifetime it has, more than any other body, been so employed as to have done service to the country and to mankind by promoting the arts of peace. Art is but the application of science to useful results, and hence science must be studied to make its application practicable. Therefore, the naval officer is very properly given a scientific education at Annapolis.

The writer might show the beneficent results accruing to the country by telling the story of many other naval expeditions, but he can here only briefly refer to a few of them, Perry's expedition, for example, which brought into the civilised community that brave little nation, Japan, now struggling for leadership in the Far East. Go to Japan and see what its people, who have built

an imposing monument on the shores of Yeddo Bay to the memory of Commodore Matthew C. Perry, U. S. N., have to say of the United States Navy. Who was it that opened also the ports of the "Hermit" nation,—Korea,—but a naval officer, Commodore Shufeldt? Captain Page's expedition up the waters of the Rio Plata River, in South America, in 1856, was another undertaking which added to our knowledge of those countries. The names of Kane and DeLong and Peary need only be mentioned to recall glorious deeds and useful results to science and to the nation accruing from the Navy's efforts.

Now let us consider that other institution belonging to the Navy which is admittedly scientific in character, but which possibly is so considered only with the idea of showing that, as it is the only scientific branch of the Navy (except the Hydrographic Office, which was once a part of it), it is out of place, and should be transferred to more harmonious surroundings.

Even if this be the case it would seem as if a little more consideration might have been given to its work than the bare mention of two names that have so stamped themselves on the scroll of fame as to remain indelible long after many of those noted have passed away. These are the names of Maury and Gilliss.

With all due respect to his eminent qualities, the foundation of the Naval Observatory was not due to John Quincy Adams, as stated. As a member of the House of Representatives Mr. Adams endeavoured to establish a "National University," of which an astronomical observatory should be a part. He based his views, as shown in his speech in Congress, on the ground that "among the first, perhaps the very first, instruments for the improvement of the condition of men is knowledge; and to the acquisition of much of the knowledge adapted to the wants, the comforts, and the enjoyment of human life public institutions and seminaries of learning are essential."

The idea of a National University has cropped out from time to time even up to the present date, but so persistently has this been fought by Congress, on the ground that the United States Constitution did not permit the use of public money for such purposes, that it was only when Mr. Carnegie offered to contribute the money for maintaining an institution of this character that it was given national recognition through the charter of the Carnegie Institute. It might have been stated that to John Quincy Adams the foundation of the Carnegie Institute is due, but not the Naval Observatory.

The Naval Observatory was not established for educational purposes; but, like its sister, the Royal Observatory of England, it is practical in every sense of the word. As a well-known writer has said of Greenwich, "first and foremost it is to assist navigation"; like Greenwich, our observatory "arose from the actual necessities of the nation"; like Greenwich, "it was founded for the benefit of the Navy and the general commerce of the realm"; like Greenwich, it has shared its work with allied sciences and contributed its full quota of observations to astronomy in general as far as was consistent with the exigencies of the Navy. But in both institutions "assistance to navigation is now and has always been the dominant note in its management."

If anyone can lay claim to be the founder of the Naval Observatory, the late Commodore James Melville Gilliss is the man. He worked long and faithfully for its establishment, until finally, when he was making what was intended to be a last visit to the chairman of the Naval Committee in Congress, one Senator, who had been the leader in opposing the scheme, said to him:—

"Did you not give notice to the National Institute last night that you had found Encke's comet?"

"Yes."

"Then I will help you all I can."

And within a week a bill was passed by the Senate for the construction of a "depot of charts and instruments," of which the Observatory was to be a part.

This was the beginning of the present Naval Observatory. Gilliss not only

prevailed on Congress to pass the law for its construction, but he built the institution. Eminent authority has recorded of Gilliss at this time that he was the "sole working astronomer of the nation." He was, therefore, the proper person to be entrusted with its installation. When the bill was passed, he had been engaged for many years in charge of an astronomical observatory built without expense to the government on Capitol Hill, in Washington, of which the late Dr. B. A. Gould, the recognised leader in astronomy of his day, has written:—

"This was the first working observatory in the United States, and the volume containing the observations during the five years, 1838-42, with the reduced results was the first American volume of astronomical observations."

He also said of the character of work done by Gilliss:—

"At a meeting of the American Association for the Advancement of Science, he (Walker) publicly stated that after an extensive series of analogous examinations, made for the purpose of deciding the relative weight to be assigned to the results of different observers, he found transit observations of only one astronomer, Argelander, which manifested equal precision with those of Gilliss."

Can higher praise for an astronomer of that day be accorded? This is history. This eminent astronomer and naval officer, Commodore James Melville Gilliss, may then well be styled the founder of the Naval Observatory.

Now as to that other officer, Commodore Matthew C. Maury, U. S. N., whose record is summed up in the brief statement that he "became superintendent of the depot," he did, in 1844, become the superintendent of the Naval Observatory (as it has been styled in every appropriation bill but one since it was founded), and he laboured so assiduously and scientifically as to produce for the country one of the grandest institutions of its kind in the world, and for himself a name pronounced with veneration in every country in the world.

At his death this sentiment took the form of resolutions gotten up in European countries in favour of "erecting a light-house on the Rocas Banks, off the north-eastern coast of Brazil, to be named after Maury, as a fitting expression of the world's appreciation of his services, and as reflecting credit on the governments which have united in this tribute to the goodness and greatness of the dead."

It might be asked, why should not his own countrymen, even at this late date, honour themselves and him by naming the light-house which Yankee ingenuity must eventually construct off dreaded Cape Hatteras, "The Maury Memorial Light-House"?

It is written that a "prophet is not without honour save in his own country"; but go into distant lands,—the countries of Asia, the states of Central and South America, the islands of the Atlantic and of the Pacific oceans,—and you may find there what are called "Greene's monuments." They show that the late Captain F. M. Greene, U. S. N., and his assistants have been there and have located the meridians of these, the principal ports of the world, and have linked them in one grand telegraphic chain to the prime meridians of Greenwich and Washington. And thus the fame of Greene, who died a short time ago in Albany with scarcely a note of praise from his own countrymen, has been perpetuated abroad to a degree that but few can hope for.

Look at some of the leading scientific schools of the country, and see ex-naval officers in control,—Harvard, Cornell, the University of Chicago, and others, and remember that the most critical community in the country offered the presidency of the Massachusetts Institute of Technology to that distinguished scholar and naval officer, Admiral Sampson.

Has the Navy, indeed, done nothing for science?

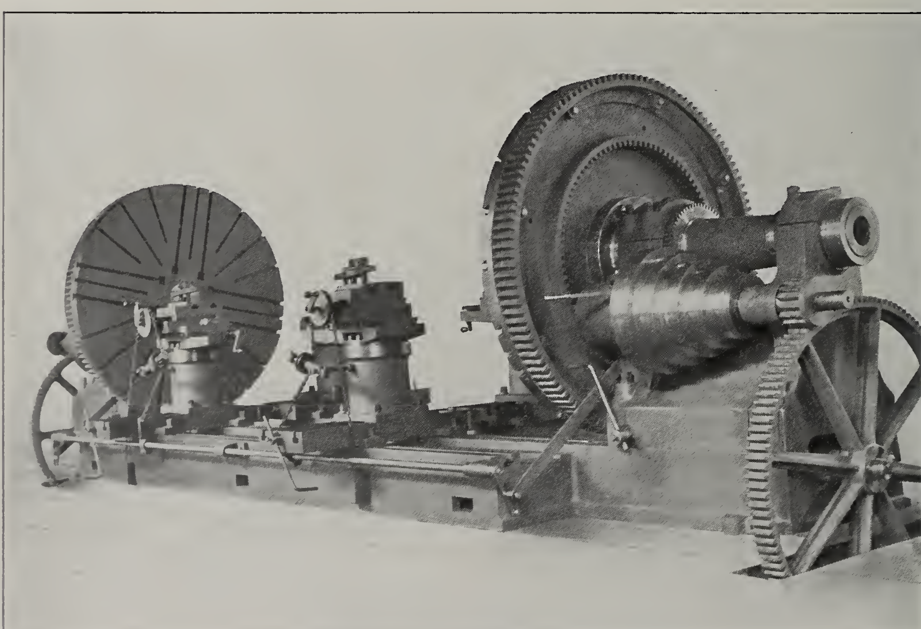
SPECIAL MACHINE TOOLS FOR LOCOMOTIVE SHOPS

EXAMPLES FROM BRITISH AND CONTINENTAL PRACTICE

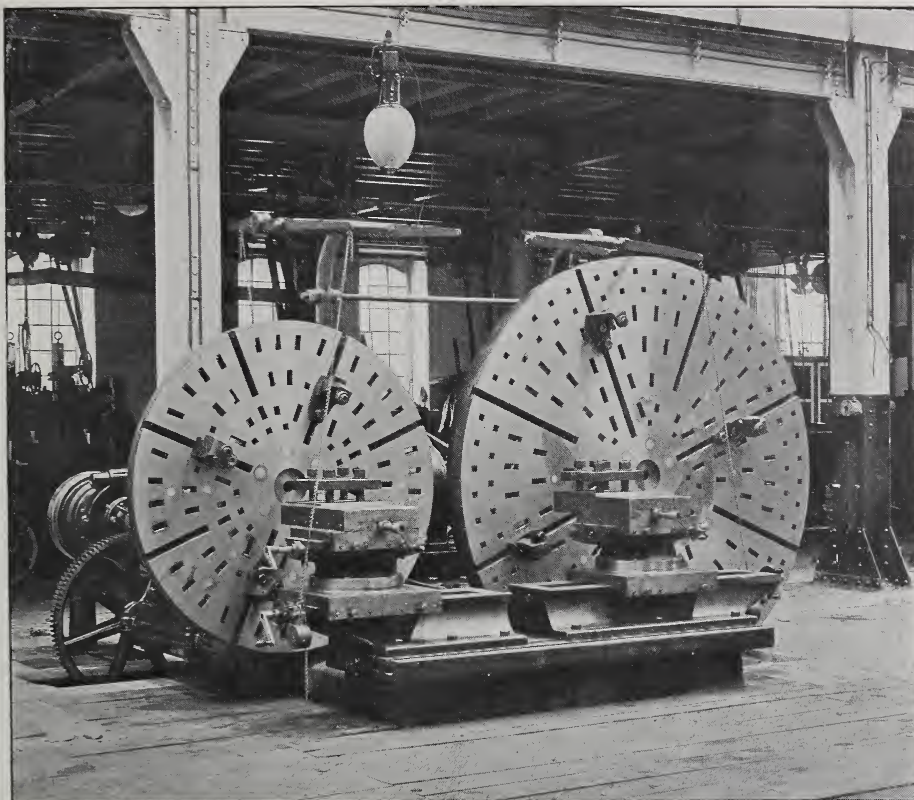
By Joseph Horner

THE locomotive industry stands apart from most branches of engineering, being approached most closely by the agricultural shops, where portable engines and road locomotives are built, and by the waggon works. The locomotive shops are among the largest in Great Britain, employing some thousands of hands, and utilising many hundreds of machine tools. The work also is mainly of a repetitive character, for although new models of engines are produced from time to time, any one type is usually built in large numbers before it is superseded. After that repairs require the retention and use of special tackle, templets, and other aids for a long period of years.

We, therefore, find in locomotive shops large groups of machines identical in form, as rows of wheel and tire-turning lathes, several machines for cylinder boring, numerous lathes engaged in turning and threading copper stays, machines for slotting frame plates, and others for grinding various parts. Almost everywhere the work is being carried out in great groups, and the machines are located accordingly, so that we have a large number of separate shops, or subdivisions of shops. The same thing is seen in the boiler department and the smithy and the carriage



A DUPLEX WHEEL LATHE FOR TURNING 6-FOOT WHEELS. MADE BY MESSRS. JOHN STIRK & SONS, HALIFAX, ENGLAND



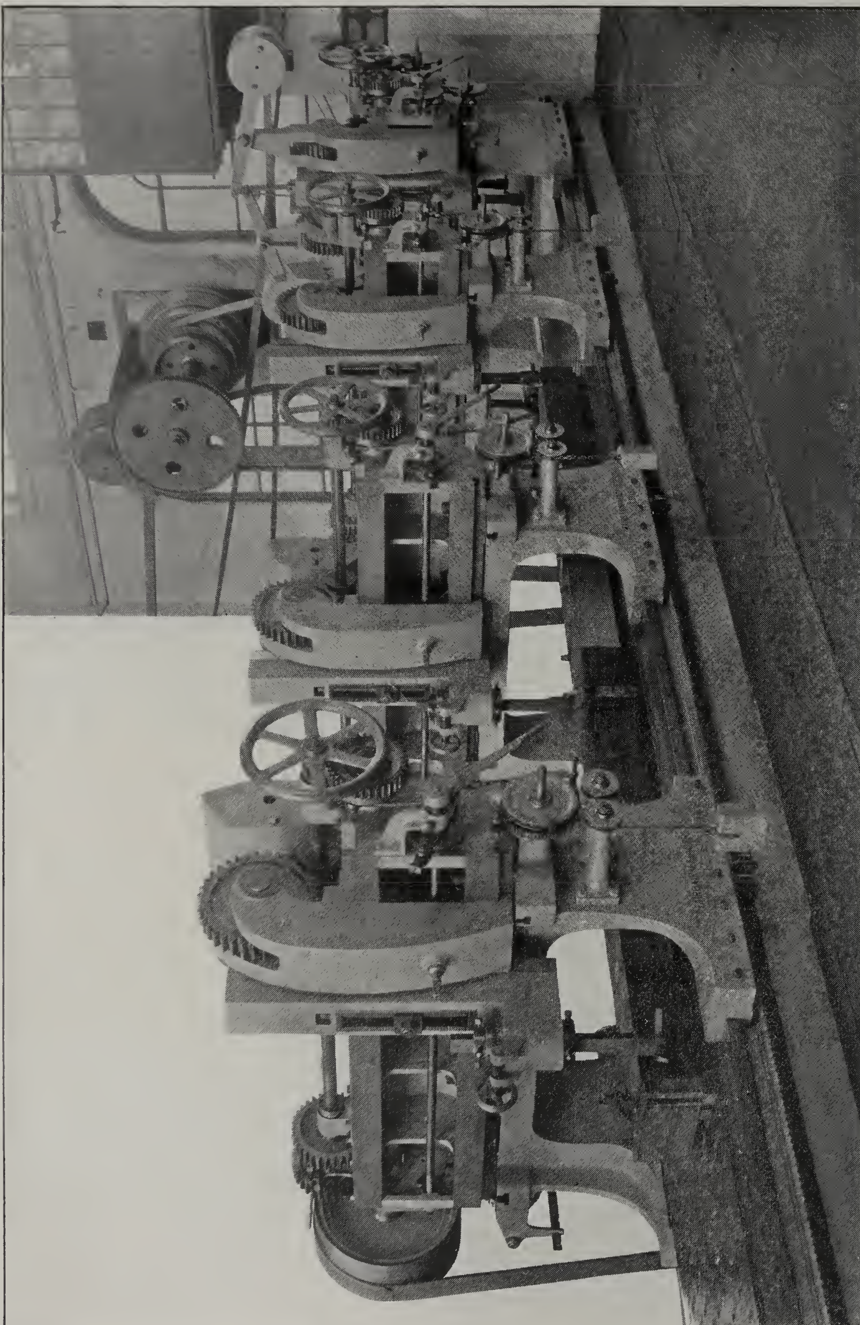
A DOUBLE-HEAD TIRE LATHE MADE BY THE SOCIÉTÉ ALSACIENNE DE CONSTRUCTIONS MÉCANIQUES, GRAFENSTADEN

shops, but the present article has reference to the machine shop and turnery only.

The natural result of this repetition of operations is that special machines are evolved in most locomotive works to perform certain duties,—machines that are not found or are but sparsely represented elsewhere. This occurs to some extent in nearly all engineers' shops, but it is very pronounced in locomotive works. It pays to have such machines when they are used year in, year out, on articles of the same shape, and of the same, or nearly the same, dimensions.

Another thing is that old tools linger long in locomotive shops. The plant is too costly to be lightly thrown out for new tools that may not prove much better than the old. Improvements are made in the existing tools, but substantially they retain their characteristics. One reason also for this is that locomotive work has not been so greatly changed from the point of view of the practice of the machine shop as that of some other departments, notably those which have been changed by the applications of electricity, or by the growth of milling, or of grinding, or by the demand for cut gears, and so on.

Locomotive practice has undergone little change in this respect, for the fact that engines are more powerful or that steel has thrust out iron makes little difference in the practice of the locomotive machine shop. The influence of certain machine tools, such as the milling machine and the grinders and the automatics, is much less felt in the locomotive shop than in others, simply because their sphere is so limited by com-



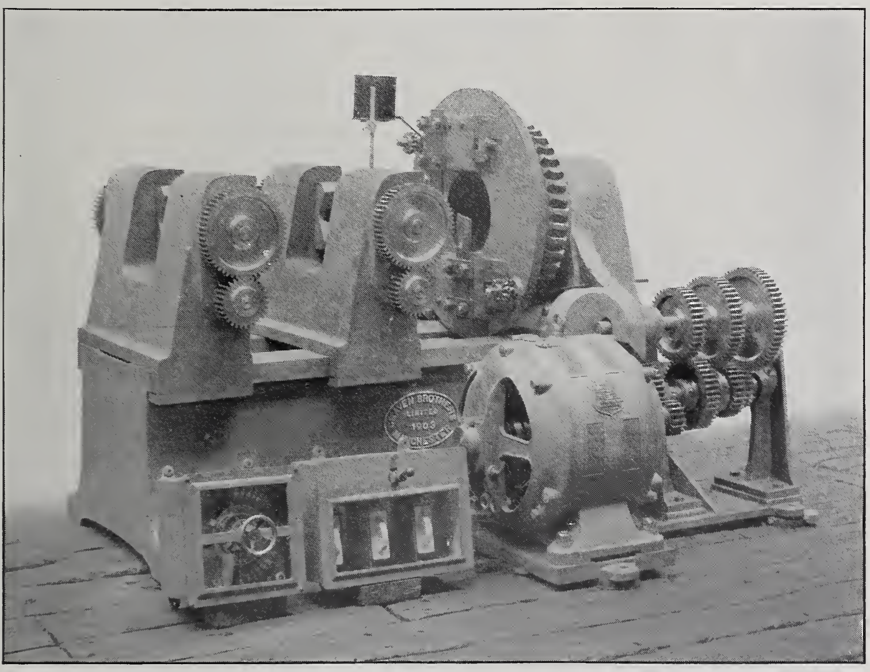
A LOCOMOTIVE FRAME-PLATE SLOTTING MACHINE, MADE BY FAIRBAIRN, NAYLOR, MACPHERSON & CO., LTD., LEEDS

parison with that of the machines for turning, boring, slotting, and planing. Milling and grinding have, in fact, been practised for twenty years or more in locomotive shops, while they were little appreciated elsewhere, while chasing lathes and screwing machines are of even longer standing.

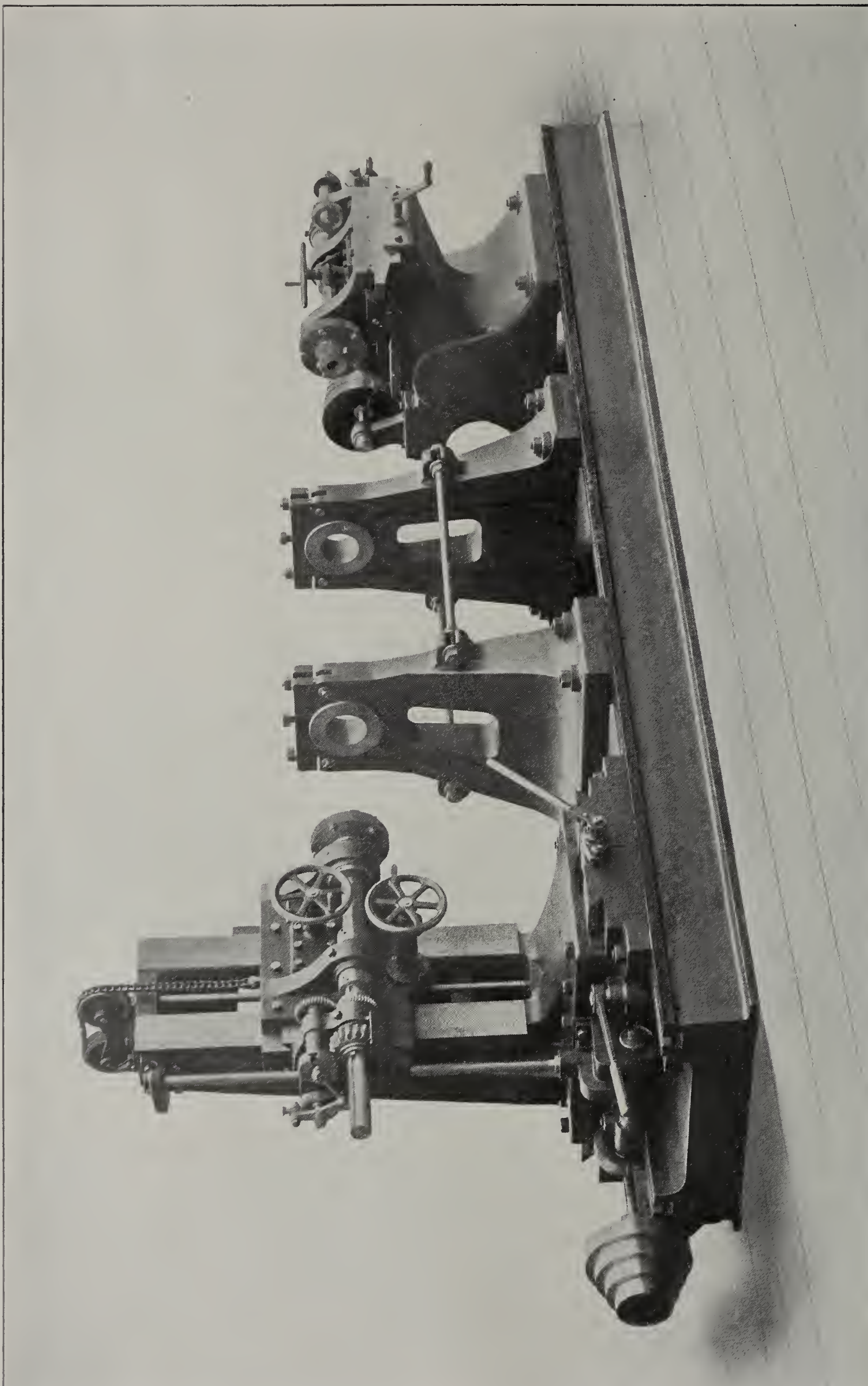
Among the principal operations of the machine shop and turnery in a locomotive works are the following:—The turning of axles, wheels, and tires, the slotting of frame plates, the boring of cylinders and of axle boxes, the planing of valve faces, the milling of ports, the tooling of rods, the turning and threading of stays and bolts, the turning of cranks, the forming of link slots, and the making of the screws, bolts, and brass fittings. These indicate the course of treatment which it is proposed to adopt in this article.

The enormous amount of wheel and tire turning and boring done has developed the numerous wheel and tire lathes that are seldom seen outside the locomotive and waggon shops. They mostly follow the regular types, but there are numerous variations in minor design; and latterly, since the introduction of electricity for driving machine tools, some of these lathes have undergone important modifications.

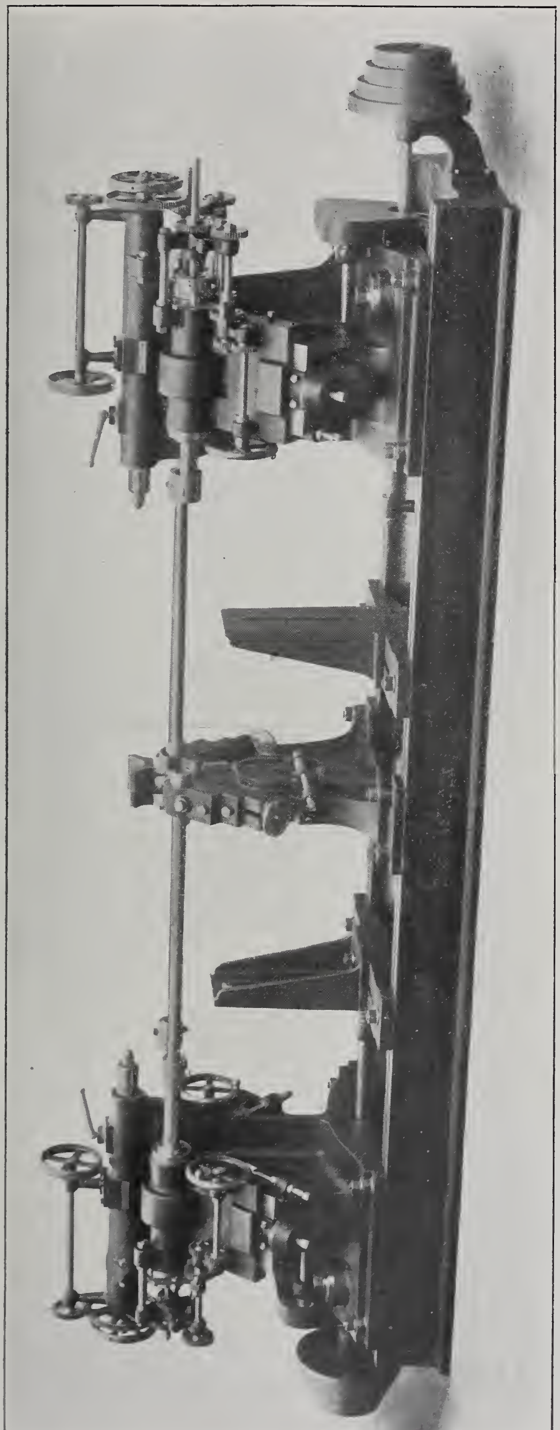
Any double-wheel lathe is limited in the range of work which it will take, both in diameter and between centres. It is a special class of machine, designed for wheels, tires and axles not varying more than a few inches in dimensions. One of the headstocks can be adjusted along the bed to suit axles of different lengths. Both face-plates are fixtures. They are geared both with external and internal rings of teeth,—the outer one for slow, the inner for quick speeds, each in a range of four or five rates, from the steps of the belt cones. A pinion on the belt cone shaft gears with the inner ring; one on a longitudinal shaft under the bed gears with the outer ring. The latter shaft is driven slowly through pinion and wheel from the belt



AN ELECTRICALLY DRIVEN CUTTING-OFF MACHINE FOR BARS. MADE BY MESSRS. CRAVEN BROS., LTD., MANCHESTER



A QUARTERING MACHINE BUILT BY THE SOCIÉTÉ ALSACIENNE DE CONSTRUCTIONS MÉCANIQUES

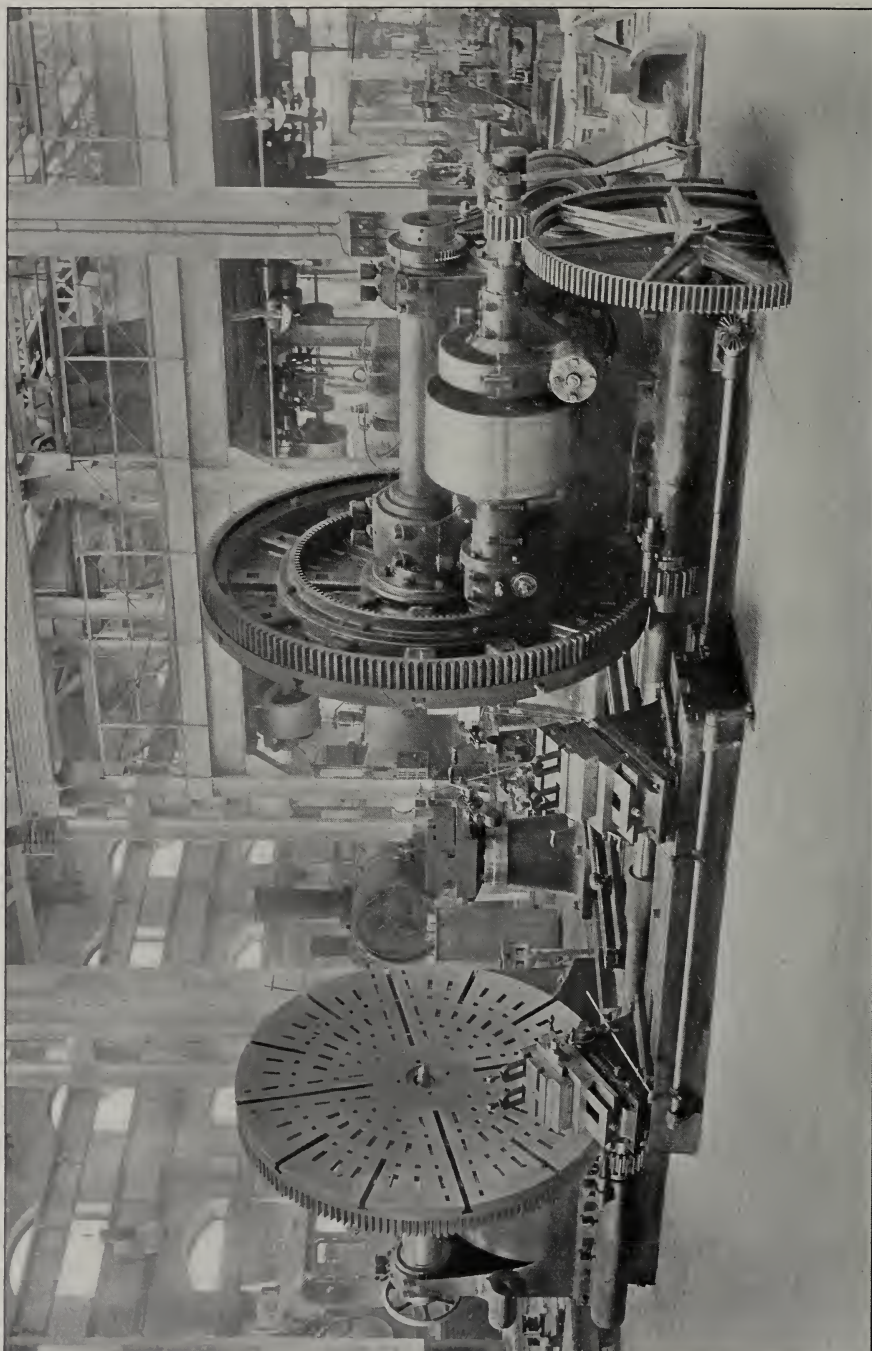


ANOTHER FORM OF QUARTERING MACHINE, FOR BORING HOLES FOR CRANK PINS, BY THE SAME BUILDERS

cones, and provision is made for rotating the face-plates either simultaneously or separately.

The pinions on the longitudinal shaft that runs down the centre of the bed, driving the face-plates, can be disengaged independently to allow the heads to work together or independently. The teeth are sometimes cast solid with the face-plates of the lathes, but the better plan is to make them separately, as rings, and bolt them on. The reason is that if teeth break it is not so serious a matter to replace a ring of teeth as it would be to replace the entire face-plate. The teeth are now very generally cut from the solid. The cones are never, in this design, put on the face-plate spindles, but on another, to one side, and the spindles are frequently of cast iron, and run in cast iron bearings,—sometimes, however, of steel, in gun metal or phosphor bronze. One set of cones drives both face-plates through the longitudinal shaft just now mentioned. This, briefly, is the broad design of the double-wheel lathes.

By the disconnection or running loose of the pinions with the toothed rings at the back of the plates, these lathes, though of special design, contain as much provision for variable duty as is required. Wheels can be turned on the axles, centred between the heads, in which case the drive is by the longitudinal shaft beneath the heads; or two tires can be bored, similarly gripped by the face-plate



AN ELECTRICALLY DRIVEN WHEEL LATHE, FOUR-FOOT HEIGHT OF CENTERS. MADE BY THE SOCIÉTÉ ALSACIENNE DE CONSTRUCTIONS MÉCHANIQUES

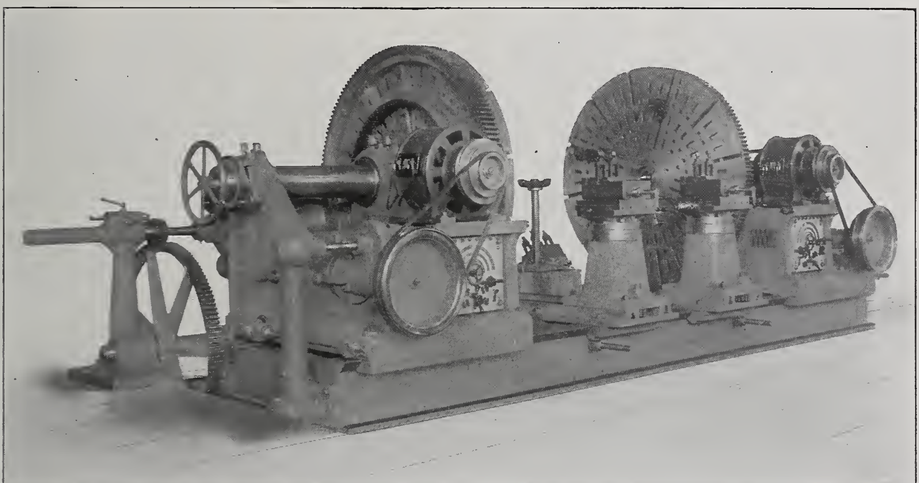
dogs; or one wheel can be bored and bossed, in which case the drive is on the inner toothed ring, direct from the cones. At the same time a wheel can be turned, or a tire bored on the other plate, the face-plate being driven by the outer ring. Usually two slide rests are fitted to such lathes, but in a good many cases there are four.

One of the first improvements on this general type is to add to the lathe as described two boring heads, so that wheels can be bored at the same time that they are being turned with the slide rests. In such a case the speed at which boring is done is much below that at which it would be performed if boring alone were in question. But this does not matter. The turning rate sets the pace, and by the time the turning is finished, the boring is also done, so that the time spent in boring is saved wholly. Similar cases occur in turret work, where turning and boring are done simultaneously.

In most of these designs the centre in the loose headstock is on a spindle fitting within the mandrel, which can be adjusted by screw and hand-wheel so that axles may be inserted or removed without having to move the mass of the loose headstock bodily. Some wheel lathes are fitted with internal sliding centring spindles to both heads, with enough travel to clear the crank-pins of wheels. Quartering attachments are fitted to some wheel lathes, sometimes single only, frequently double.

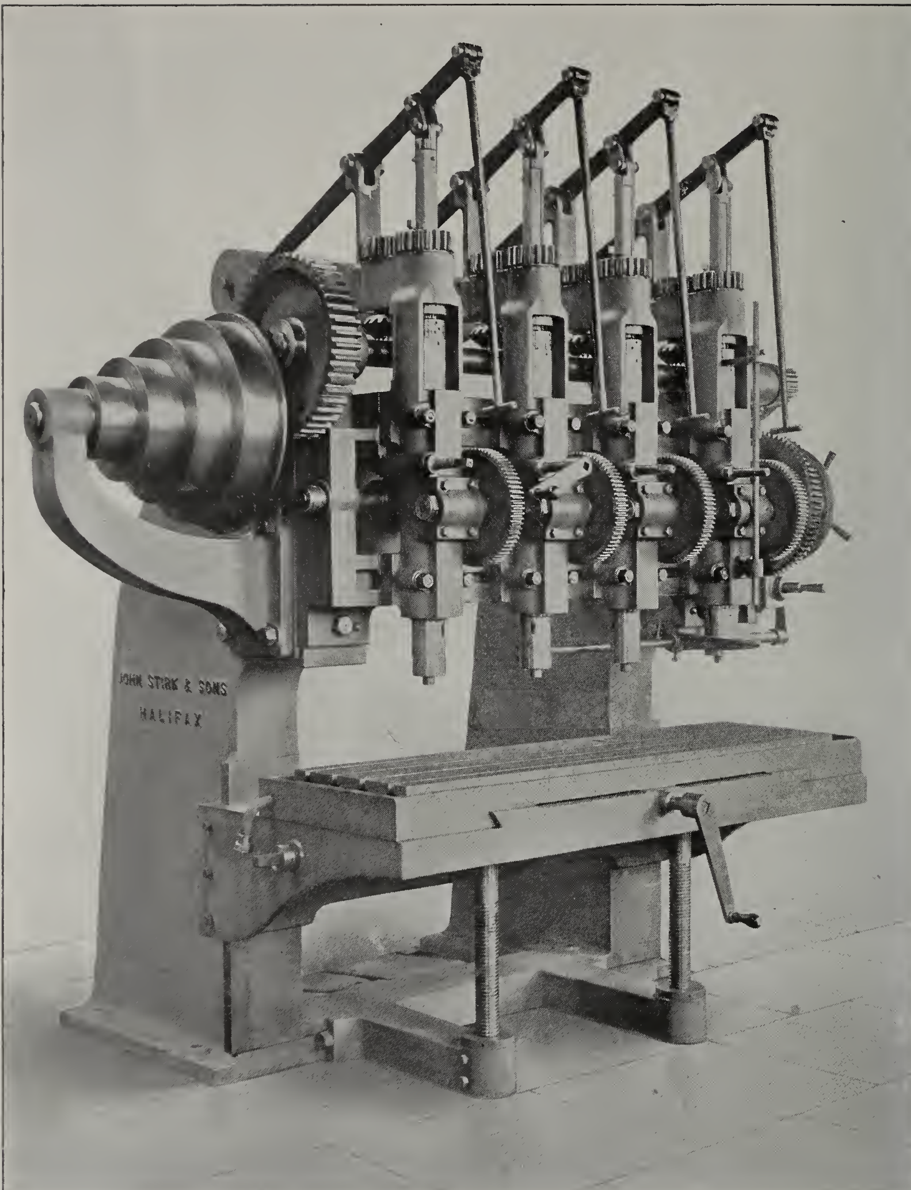
The details of boring adjuncts to the wheel lathes vary. In one design the boring bars are carried on headstocks that are bolted down to the bed. They are fed forward with a screw regulated by ratchet teeth, and pawls worked from cords actuated from overhead.

In the lathes made by Ernst Schiess, of Düsseldorf, the bar is fed by a slide, in which the bar is clamped with a hinged cap, and the slide is fed forward by a ratchet and screw. The bar passes through the headstock mandrel, and has its bearing in phosphor bronze. In these cases the bar only has a longitudinal feed, the wheels being revolved by the face-plates.



A REAR VIEW OF A LATHE SIMILAR TO THE ONE SHOWN ON THE OPPOSITE PAGE

The motor-drive for the wheel lathe of the Société Alsacienne de Constructions Mécaniques, of Grafenstaden (see cut above), is a decided improvement on the standard form with overhanging cone pulleys at one end. The motor drives both the face-plates and the feeds, through worm gears. A feature which is in contrast with British practice is that the driving shaft carrying the pinions that gear with the face-plates is



A FOUR-SPINDLE DRILLING MACHINE. MADE BY MESSRS. JOHN STIRK & SONS, HALIFAX, ENGLAND

carried along the back of the lathe instead of beneath. There are four rests, two at the front and two at the back. This is usual in the most complete lathes, and they are operated either from an eccentric connecting-rod, from the rear of the fast headstock, or from overhead, —methods that are familiar and that vary little in different lathes.

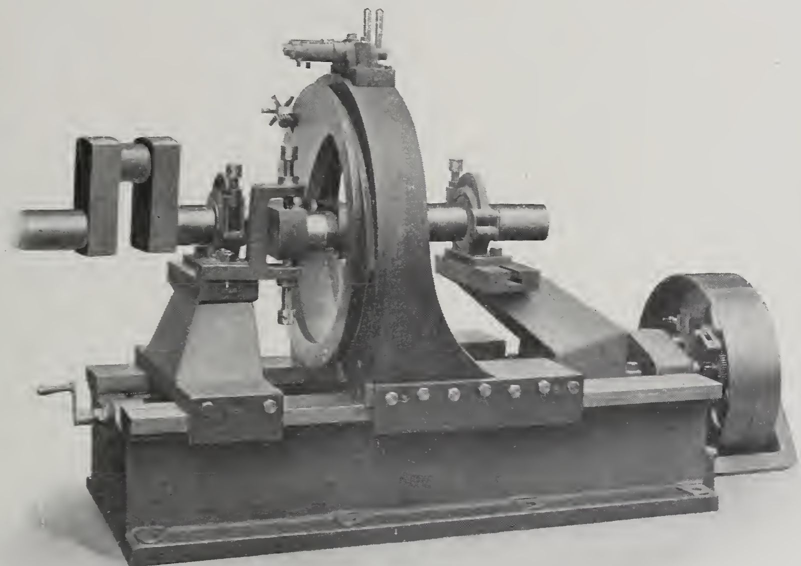
Double-wheel lathes are variously fitted with adjuncts to make them capable of meeting all conditions that are likely to arise. Sometimes steel-cupped centres are fitted for carrying the axles

by their collars instead of by their centres. Sometimes the weight of the wheels and axles is taken by supports bolted to the bed and receiving the axle journals in cupped bearings. Jaws and dogs of various types are fitted to the face-plates. Special slide rests are sometimes fitted for turning up axle journals. Cranes also are fitted. A special device is employed in many cases to permit of re-turning locomotive and waggon wheels irrespective of the centres on which they were originally turned. The journals themselves are grasped. In one case self-centring, four-jawed chucks on the face plates are used.

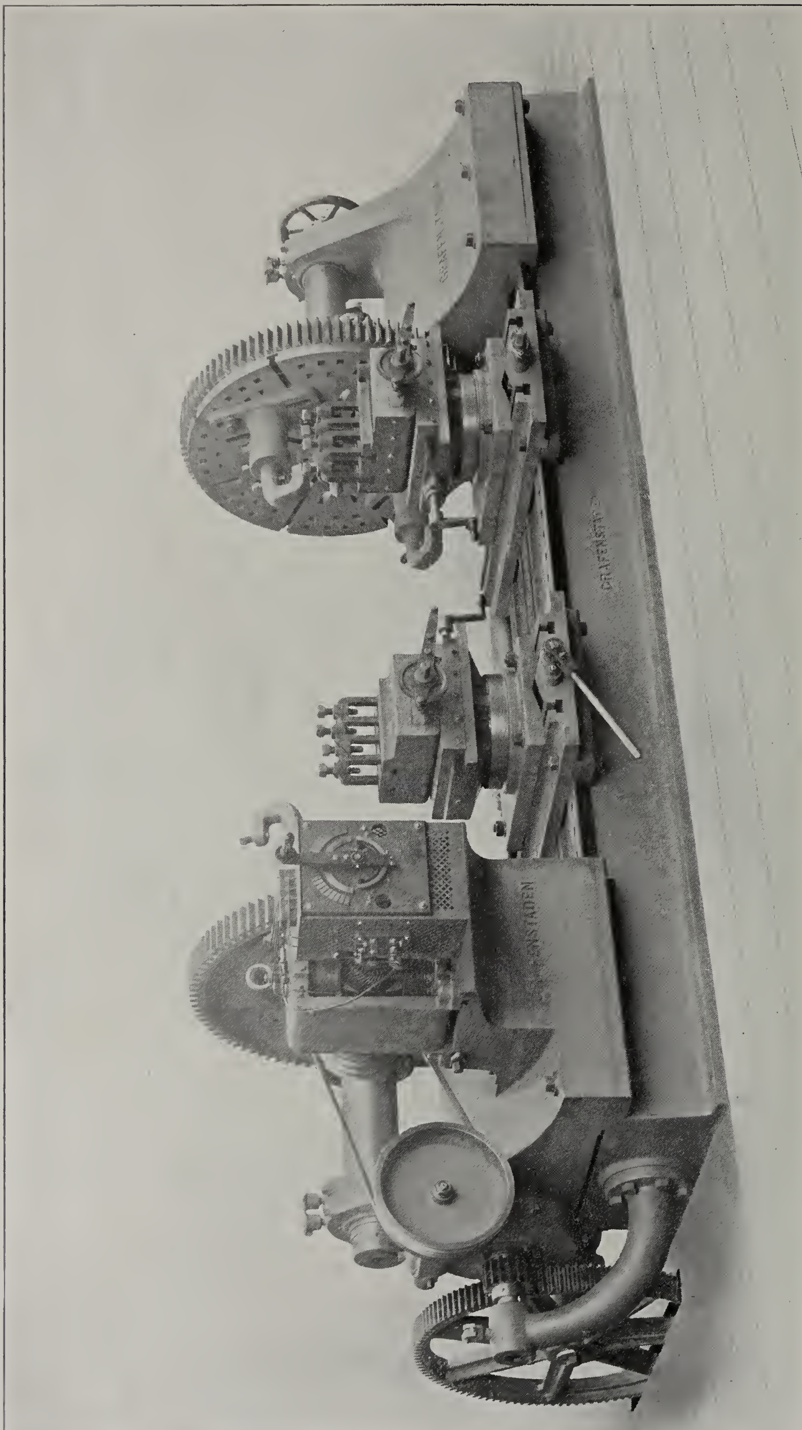
There is a type of wheel lathe made for truing-up axles in which the driving is effected by a belt running on the tread of one of the wheels. The self-acting feeds are obtained in various fashions. In one case a belt drives from about the centre of the axle to a pulley on a long shaft below, turning in bearings attached to the bed. From this shaft belts come up and turn the feed screws of the longitudinal slide of the rests, which are fitted with pulleys instead of handles. In another style the feeds are obtained from overhead, using slotted plates, with cranks, cords and ratchet feeds. The practice of driving on the wheel treads leaves both ends of the journals free to the turning tools.

For turning and boring single wheels apart from their axles the single wheel lathe is used. This also can be fitted with a boring bar, so that both operations can be performed at once. The headstocks of these lathes follow the design of the heads of the double wheel lathes, in being driven by stepped cones to one side, in having external and internal rings of teeth on the face-plate, for slow and fast driving, etc. When wheel lathes are made double, the heads and face-plates are generally set side by side, and a bed in front carries the rests for both heads.

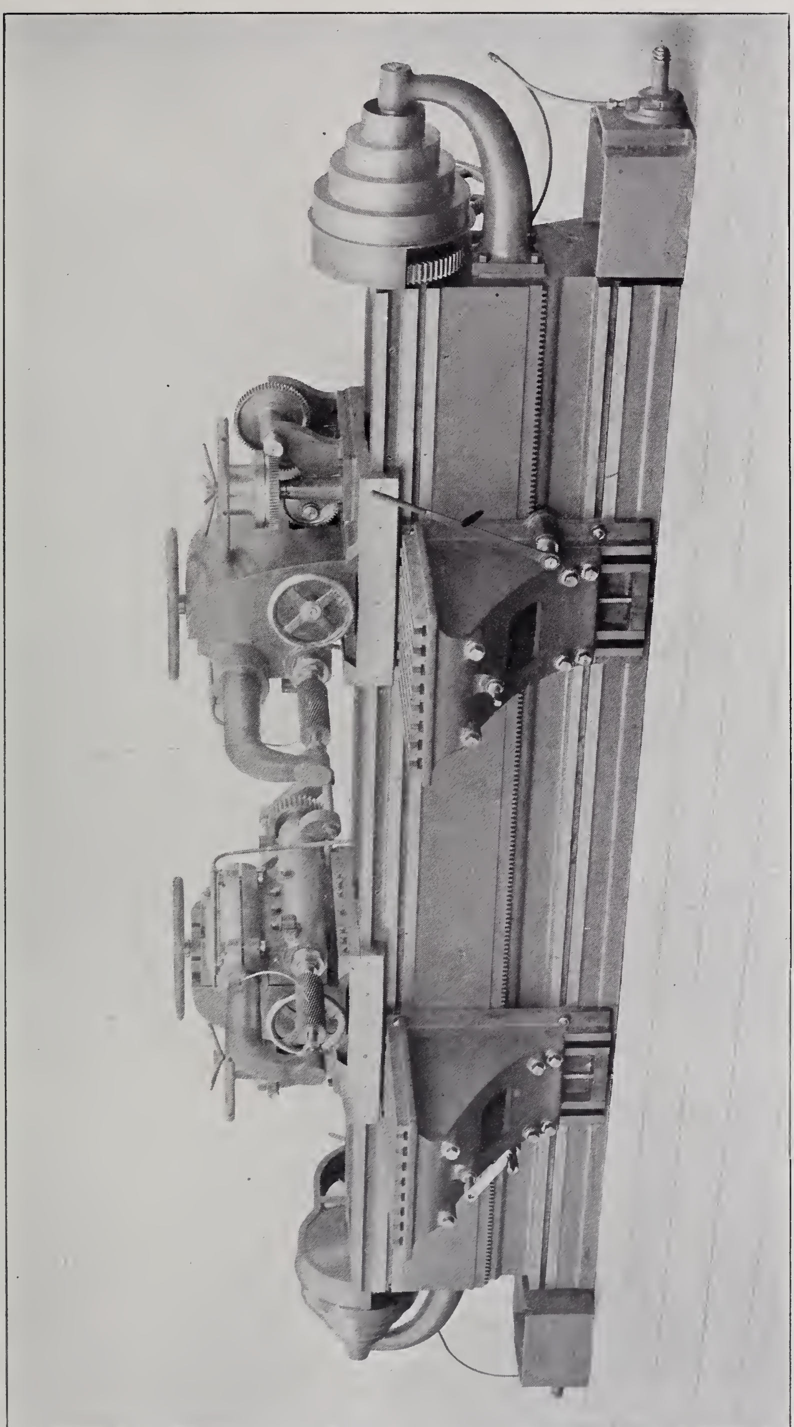
The lathe for tire turning and boring is a face lathe,—very frequently worm-driven, with three speeds through cones



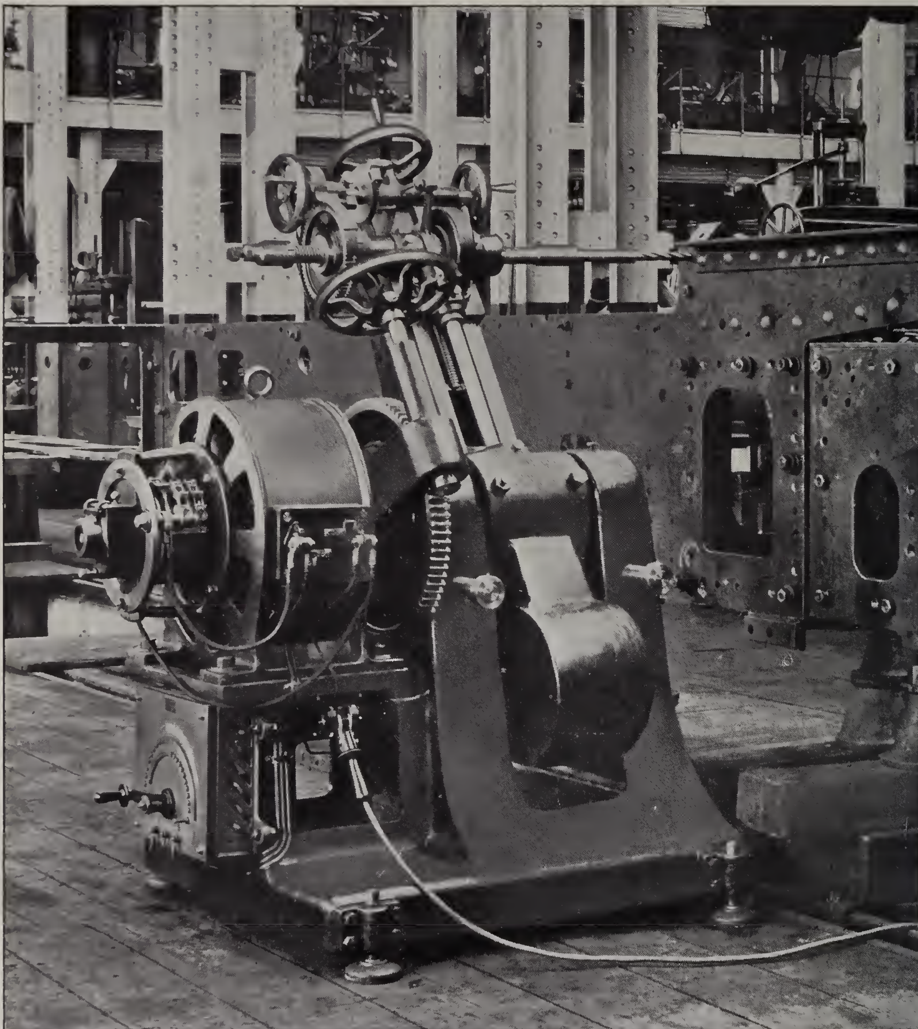
A CRANK-PIN TURNING MACHINE, MADE BY MESSRS. E. CAPITAINE & CO., FRANKFORT-ON-MAIN, GERMANY



A DOUBLE WHEEL LATHE, MADE BY THE SOCIÉTÉ ALSACIENNE DE CONSTRUCTIONS MÉCANIQUES, GRAFENSTADEN



A DOUBLE-HEAD CRANK MILLING MACHINE FROM THE SAME BUILDERS



A PORTABLE ELECTRIC DRILL WORKING ON LOCOMOTIVE FRAMES. MADE BY THE SOCIÉTÉ ALSACIENNE DE CONSTRUCTIONS MÉCANIQUES

and two rests. The worm-wheel is at the back of the face-plate. The spindle is of cast iron, running in bearings of cast iron, gun metal, or phosphor bronze. Tire-boring lathes with worm-drive sometimes have worm-wheel separate, sometimes cast in one piece with the plate. The former is generally much smaller than the latter, but the big wheel is much preferable. Another thing is that provision is made in one type at least for drawing the worm out of gear from the wheel, to permit of pulling the face-plate round by hand when chucking a tire.

This comparatively old method of driving lathes by worm gear instead of through a ring of spur teeth is retained in many wheel and tire lathes, both in Great Britain and on the Continent. It is a smooth and powerful drive, and now that properly cut worm gears are easily obtained, there is no reason why it should not be adopted more than ever.

In quartering machines the weight of the wheels and axle is taken on vee

bearings, adjustable for height, in addition to the centring. The wheels are clamped to these bearings. The boring spindles have a traverse of about 15 inches, two rates of speed and two feeds, and rapid hand movement. Sometimes a pair of rests is attached to the boring bars for turning crank-pins.

A special tool worth noting is a vertical wheel boring or wheel centre boring lathe, fitted with a small jib crane for lifting the wheels in and out. The wheel, or centre, is gripped by the jaws of the horizontal face-plate. This is double-geared, and has a large range of speeds which can be changed without stopping, as also can the vertical feeds of the tool bar. In the combined boring and turning machines there are two tool bars, each one of which can be used for turning, or one for turning and the other for boring.

The axle turning lathe is a very special tool. Its sole function is that of turning the axles of rolling stock both of waggons and locomotives. The axles are centred on movable poppets, two loose poppets being adjustable on each end of the bed, and they are driven with a peculiar central, hollow headstock, through which the axle passes and by which it is rotated. The headstock is back-geared. The poppets are sometimes made with transverse slides, the object of which is to permit them to be slid backwards out of the way when the axle is inserted and when it is withdrawn. There are two saddles, with compound slide rests operating on each journal of the axle at once. They are driven by lead screws, and have quick return traverse by hand, and by rack and pinion. The driving is done from one end by stepped cones through back gears.

The crank-axle turning lathe is another machine tool which, in its most complete forms, is capable of operating on four or five sections simultaneously, since it is usually fitted with slide rests at the front and back. While some are turning, others are facing down the webs. Such lathes are treble-geared.

The turning of locomotive crank-pins is best done by special machines in which the tools rotate around the cranks, fixed in the machine. There are two types at least of these, one using a single tool, the other two tools on opposite sides. The main feature of the design is that of an outer circular framing or housing, within which the tool-controlling arrangement revolves by an internal wheel and pinion, the whole travelling on the machine bed, and having a range of speeds and feeds. Screws permit of adjustments of the cutter, or cutters.

Quartering, crank-pin turning and eccentric-pin turning are combined with axle turning in a machine by Ernst Schiess, of Düsseldorf (represented in Great Britain by Mr. W. Stamm, of 25 College Hill, E. C.). By the courtesy of Mr. Schiess the writer is enabled to give detail drawings of this machine, which would be difficult to understand from a photograph alone. The reproductions appear on pages 84, 85 and 87.

The elevation of the machine in Fig. 3 shows it when arranged for axle turning. The axle is clamped on a central bed, and the operations of quartering, etc., are performed by the headstocks to right and left. These differ in design, the one to the right having horizontal advancements for the boring and turning apparatus, that to the left has vertical adjustments.

The mechanism of each headstock spindle is driven from a separate countershaft through a three-stepped cone pulley *A* situated on each head. These pulleys drive to the spindles through mitre and worm gears. There are two sets of driving gear for each headstock, —the main set for use when turning axle journals; the other, for turning crank-pins and boring crank-pin holes. The first named are in fixed bearings; the second, by virtue of their vertical and horizontal movements, permit the boring of holes at right angles (quartering) within a range of crank throw of about 9 to 16 inches.

When boring and crank-pin turning are being done, the wheels *B*, Fig. 3, are disconnected from *C* by moving the slide *D* on the left-hand headstock downwards, and the slide *E*, Fig. 2, on the right-hand headstock outwards, to

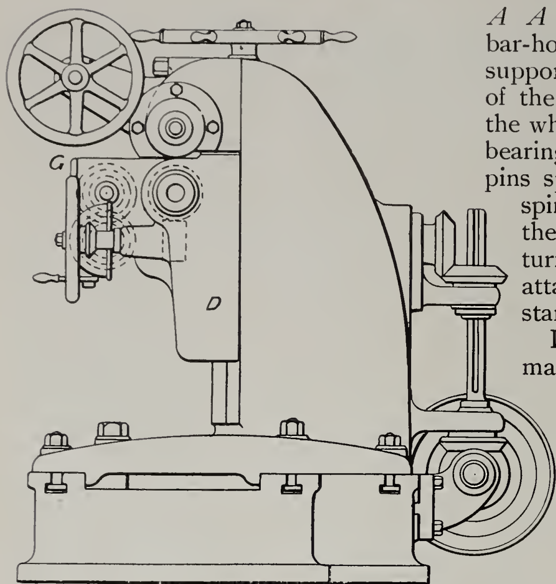


FIG. 1.—END VIEW OF THE LEFT-HAND HEADSTOCK OF THE MACHINE SHOWN IN FIG. 3

A A slotted for cutters. Adjustable bar-holders are provided on the rest support for carrying the outer ends of the bars. At this time the axles of the wheels are clamped in the steady bearings *B B*. For turning the crank-pins special fittings are attached to the spindles, or to the face-plates, and these each carry a tool rest. For turning eccentric pins other rests are attached to the face-plates, having star feeds.

Double cutting-off and centering machines for axles are another special type of tool. The rests are fixed, and the centering or gripping heads are adjustable along the bed. The axles revolve in the latter, and the tool slides are adjusted by rack and pinion to suit different lengths of axle, and are fed by hand or by power, together or separately. The centering heads driven from overhead are slid on the tool carriages by means of a lever.

A parting, or cutting-off machine for bars, for built up locomotive cranks and similar service, is shown on page 73.

permit of which the operating shafts are splined to allow their mitre wheels to slide upon them.

The boring feed of the left-hand headstock is effected by feeding the spindle by means of a split nut and threaded sleeve *F*, Fig. 3. Three variations can be given by means of the stepped gears enclosed in the box *G*. The boring feed of the right-hand headstock is imparted by a longitudinal sliding of the boring head *E* solidly. Hand-wheel movements are included in each case for feed and reversal.

In Fig. 3 a pair of wheels is held for turning the axle journals. They are mounted between centres, and driven by the dog on the left-hand headstock. The two slide rests *H H* have chain and ratchet feeds.

The design of machine permits of boring the crank-pin holes, turning the crank-pins, and turning eccentric pins. Fig. 4 shows the machine arranged for boring the pin-holes simultaneously. This operation is performed by two boring bars

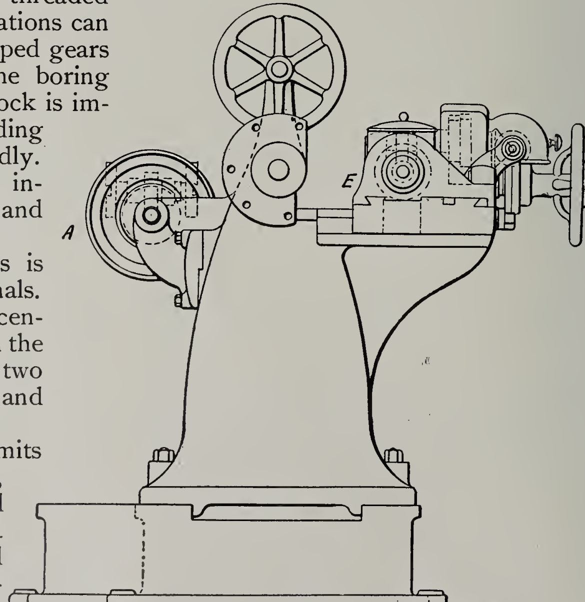


FIG. 2.—END VIEW OF THE RIGHT-HAND HEADSTOCK

The headstock is hollow, with a hole to admit the bar to be severed. The cutting-off tools are carried on the face-plate in two slides fitted with star feeds, which feed them forwards automatically towards the centre. One parting tool is a little wider at the cutting point than the other, so giving clearance for the narrower tool. The revolving ring is driven by a worm and wheel. An adjustable steel tail pin takes the pressure of the worm. The drive is by a 5 B. H. P. motor, the spindle of which is fitted with a rawhide pinion. The latter drives the second motion shaft, which has three sliding pinions engaging with three machine-cut wheels, giving three changes of speed to the face-plate carrying the cutting tools. The bar to be severed is held with vee jaws in the vices, which open and close simultaneously, so centering the work. This machine is made by Messrs. Craven Brothers, Ltd., of Manchester.

Milling done on the planer type of machine fills a considerable place in locomotive work. The utilities of double-head milling machines also are greatly appreciated when a number of pieces have to be faced off to the same definite lengths, as in the distance pieces between locomotive frames. Or two sets of axle boxes can be milled independently, since the carriages can be worked independently, as well as in unison.

Frame-plate slotting machines are another special type designed for one class of duty only. Cylinder boring is done on machines of various types. They are made for this work only, and their dimensions are limited to suit smaller or larger locomotives. They comprise standards to carry the boring bar, and a bed which is fixed to receive the cylinders,—that is, the elevating table of the common boring machine is absent.

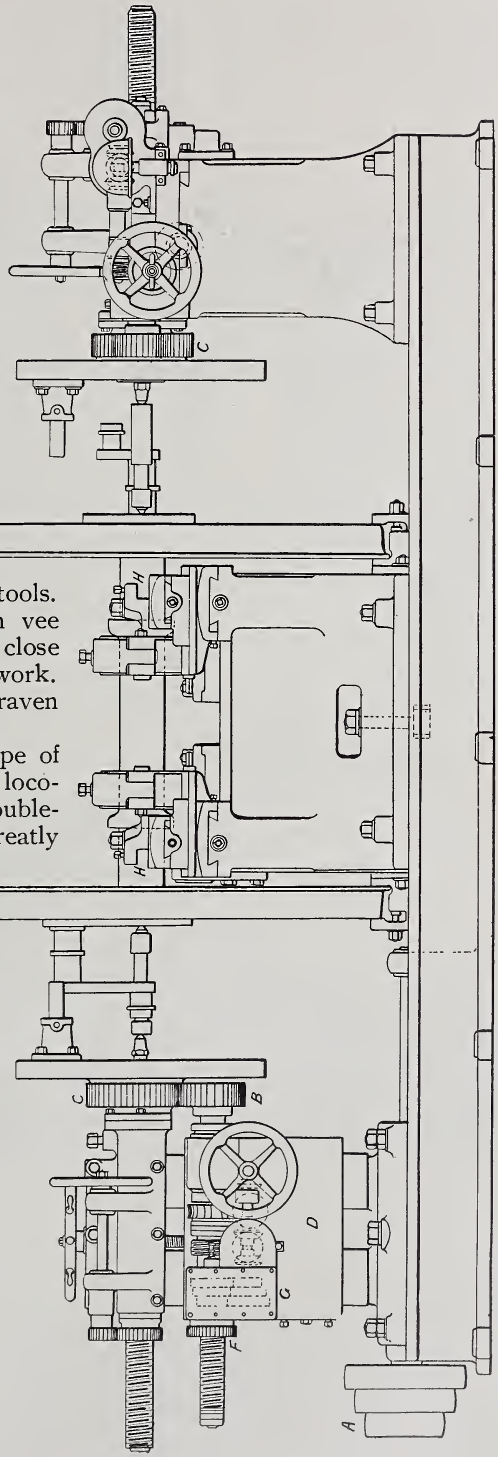
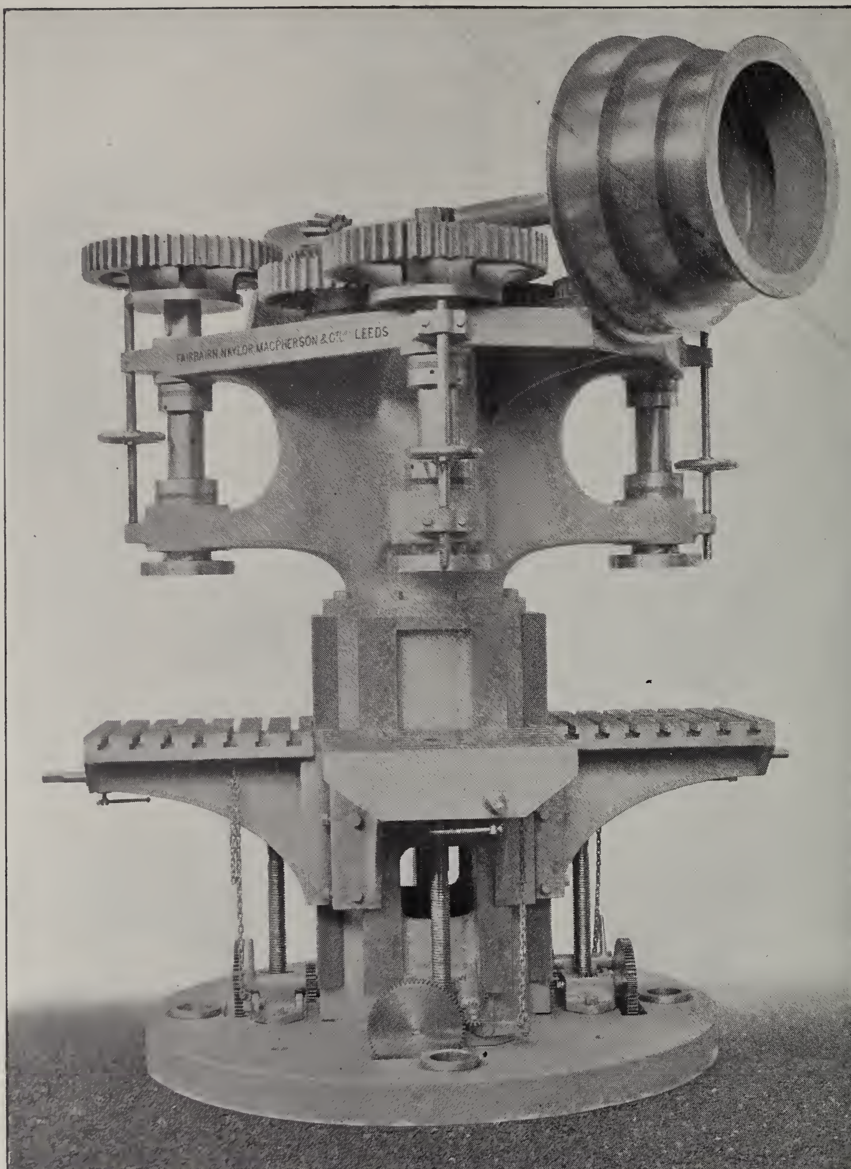


FIG. 3. — A MACHINE FOR QUARTERING, CRANK AND ECCENTRIC PIN TURNING, AND AXLE TURNING, MADE BY ERNST SCHIESS, DÜSSELDORF, GERMANY



A QUADRUPLE BORING MACHINE, MADE BY FAIRBAIRN, NAYLOR, MACPHERSON & CO., LTD., LEEDS. THE VERTICAL SPINDLES WORK INDEPENDENTLY. THE TABLES HAVE SELF-ACTING VERTICAL MOTION WITH SELF-ACTING STOPS

The bar is not much smaller than the boring head, so that the maximum stiffness is ensured. Two facing heads are provided in order that the boring and facing of both flanges can be done simultaneously. The bar is made so that it may be withdrawn endwise to permit of the insertion or removal of the cylinders. In some designs the boring bar is driven through a worm and large worm-wheel; in others a spur drive is adopted. There are several rates for speed and feed to suit roughing and finishing cuts and variations in bores.

There are a good many devices for boring cylinders without rigging them up on boring machines or lathes. The apparatus is fastened to the flanges, and the bar, or the boring head, is driven by worm gear. In another design the cylinder is bolted down to a framing in the ends of which the bar has its bearings. These machines are used to bore the cylinders in place, or to rebore them after wear has occurred. The feed of the cutter is through differential gears, in the fashion of ordinary bars.

It is rather interesting to observe the recent growth of portable tools. We are familiar with the pneumatic tools; but, apart from these, a vast amount of portable mechanism is used, the locomotive shops possessing a fair share. Double and triple bar machines are used specially for double and compound cylinders, so that the boring proceeds simultaneously, and the correct centres and absolute parallelism of the bores can be relied on. Valve face planing in place is another operation which is done to avoid the dismantling of cylinders.

The practice of grinding in locomotive shops increases. The journals of axles are ground on special forms of machines with two emery wheels, so that both journals are finished simultaneously. Link grinding also is a very important branch which has been practiced for many years past. The link is swung from a centre equal to its radius, and an emery roller finishes out the slot in a manner which cannot be attained in any other way. The grinding of hardened holes and bushes in rods and motion work is another operation which is now indispensable in the locomotive shop. Flat surface grinding is not yet practiced to so great an extent as the above named; but its utilities are constantly increasing, the slide bars and other flat pieces being finished thus with great accuracy.

The turning and threading of bolts and stays is done on special forms of lathes provided with chasing bars. Latterly this work in many shops has been put on automatic screw machines of the ordinary type, thus eliminating the hand operator. The enormous quantities of bolts and screws required afford an excellent chance for the employment of automatics, and the locomotive shops are not slow to avail themselves of this aid.

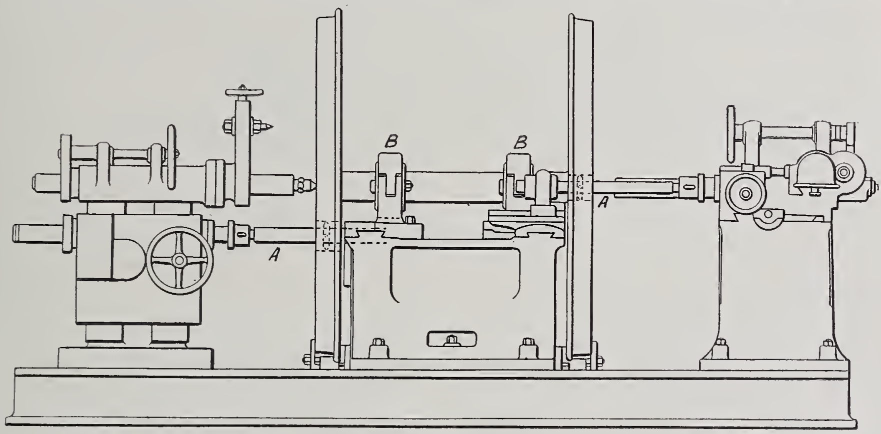


FIG. 4.—THE MACHINE SHOWN IN FIG. 3 ARRANGED FOR BORING CRANK-PIN HOLES SIMULTANEOUSLY

Portable drilling machines, for use on partly erected locomotives, are in constant use, drilling holes and tapping and studding them on different portions of the frames. A peculiar form of drill is used for drilling the holes for the retaining screws of wheel tires, the drill working from the inside of the wheel rim in a confined position.

The special tools used in locomotive

shops are in many cases designed and sometimes built in the works, to suit some particular class of machining. A considerable number of the most ingenious machines have been thus evolved, which are now regularly made by manufacturers. Improvements are always being made, and most shops possess tools peculiar to them, types which one will not find elsewhere.

Current Topics

THAWING out frozen water service pipes by electricity became popular in many a household during the past winter, so that what was formerly a relatively costly, an exceedingly slow, and an all-around inconvenient process, involving the digging up of streets and the building of fires in the excavations, resolved itself into an interesting electrical experiment—cheap, quick, and thoroughly efficient. Briefly, the method has been to complete an electric circuit through the frozen water service pipe by attaching one wire of the circuit to the street hydrant and the other to a faucet in the building. The iron pipes being much better electrical conductors than the frozen earth, the electric current followed them and heated them sufficiently to melt the ice in a comparatively short time. In cases where street hydrants were not conveniently located, the circuits were completed by connecting up pipe outlets in two adjoining houses; but in the case of isolated buildings there remained no other way of getting one of the terminals than by digging down at some point in the street, or outside the building, to reach the pipe. Even in this extremity, however, there was not that trouble and delay which attended the old wood or coal fire method, while there was greater certainty of action.

THE electric current usually was taken from conveniently located electric lighting circuits, the voltage being reduced to from 20 to 50 volts by means of portable step-down transformers carried on waggons, and for further regulation of current and pressure suitable resistances were employed. In some instances portable generating sets were employed, consisting of steam or gas engine-driven generators, with their accessories, and in still other cases storage battery outfits, moved about from place to place on waggons, were used for the work. The principal point to be guarded against was excessive heating of the pipes,—sufficient to injure them. For

large pipes, heavy current of low voltage is used, and for small pipes comparatively low current is employed. In some instances a current ranging from 25 to 300 ampères has been employed, and in the case of frozen mains as much as 1000 ampères have been utilised for a few minutes. With a service pipe 75 feet long, a current of 275 amperès, at about 18 volts pressure, has raised the temperature of the pipes to about 145° F. In at least one instance, it is interesting to note, the best part of a day was wasted in the attempt to thaw out electrically what seemed to be an unusually refractory pipe, before it was learned that earthenware water mains,—non-conductors of electricity,—were used in that particular place. That is the only case in which the electric process is known to have been a failure.

Making machinery foundations elastic so as to minimise or even altogether prevent vibration of buildings, is a recently much-mentioned subject, special reference having been made to the uses of a particular new kind of impregnated foundation felt which is claimed to have given very satisfactory results. It has been spoken of as intended chiefly for insertion beneath rails, girders and machine beds, and as being made in sheets of varying thickness,—from ⅜-inch to 1½-inch. The felt is impregnated with mineral fat, so as to be moisture-proof. In Germany it is said to be in extensive use in connection with steam hammers, pumps, steam engines and much other machinery; under bridge girders, railway ties, rail chairs, and car bodies; and between columns and joists in buildings, and on shipboard to separate machinery from steel decks and bulkheads. The sheets are made in different sizes up to 60 inches in length by 30 inches in width. Felt mats have for many years been used as anti-vibration expedients, so that there is ample reason to expect satisfaction from the employment of the so-called "foundation felt" here noted; but it may not be amiss to observe that in many instances the apparent desirability of its use is indicative simply of something wrong in the machinery installation. Small earthquakes from the operation of a steam hammer, and trembling buildings from fast-running machinery, often are proofs that the machinery has not been properly put in. Foundations rightly proportioned and rightly laid would materially restrict the market for special foundation preparations and confine their use to the underlaying of rail chairs, bridge girders and such other more appropriate things as have already been mentioned in this paragraph. With these their services would seem to have a fitness entirely lacking where moving machinery is concerned.

In telling of the use of steel for shipbuilding in his late presidential address before the Institution of Civil Engineers, Sir William H. White mentioned the fact as noteworthy that the iron used in mercantile shipbuilding remained practically always an untested material, the maker's brand being usually accepted as a sufficient guarantee of quality, supplemented, of course, by the practical test of shaping and working the material in building ships. The British Admiralty followed a different course from the first, insisting on tensile and forge tests for all iron plates and bars, for which proof of qualities they had to pay a much higher price. With the advent of mild steel came a complete change in private practice, as, from the first, steel was carefully tested. There was, indeed, a suspicion of steel, arising from the erratic behaviour of early specimens of that material used for special ships; and it is curious now, with a quarter of a century's knowledge of the greatly superior strength and ductility of mild steel, to remember that it was so distrusted while iron was accepted without question. The French took the lead in the introduction of mild steel for shipbuilding, and an eminent naval architect, the late M. de Bussy, had much to do with the matter from 1872 onward. Sir Nathaniel Barnaby at once saw the possibilities of the material, and called on

British manufacturers to furnish supplies. The response was prompt. Sir William Siemens undertook the contract at his Landore works, and in 1875 the first two vessels built of mild steel for the Royal Navy,—the *Iris* and *Mercury*,—were commenced. At first the new material was somewhat dearer than the high quality of tested iron previously used; but it soon became cheaper, and iron almost immediately fell out of use for new warships. For merchant ships the use of mild steel began a little later. In 1877 the Committee of Lloyd's Register sanctioned its use, and in 1879 Messrs. Denny built for the Allan Line the first large steel steamer, the *Buenos Ayrean*, of 385 feet in length and nearly 4200 tons. Up to 1891 mild steel was dearer than the untested iron commonly used, and this fact, as well as a lingering doubt as to the trustworthiness of the material, delayed its extensive use. In 1885 only 35 per cent. of the aggregate tonnage built in iron and steel for the merchant marine was of the latter material. After that date steel gained rapidly, and for the last ten years it has practically superseded iron for merchant ships. Iron is now used only for trawlers and small vessels.

Mild steel used for shipbuilding ranges from 26 to 32 tons per square inch in ultimate tensile strength, and its elastic length (or "yield point") is at 16 to 17 tons per square inch. It is from 25 to 30 per cent. stronger than the best quality of iron formerly used in Admiralty practice, and gains even more upon iron such as was used in merchant ships. In ductility and working qualities it is vastly superior to iron, and operations such as flanging, goggling, and bending are now performed on steel in the cold condition, which with iron required to be done hot, or were not practiced because of their difficulty and cost. The shipbuilder also commands the supply at moderate cost of plates and bars of dimensions and sections not obtainable with iron, and thus gains in weight in addition to the savings due to superior strength. Increased carrying power is, of course, the chief reason for using steel; but estimates vary greatly as to the saving in weight in different classes. The universal adoption of steel is ample evidence of its commercial advantage, and experience proves that its superior ductility adds greatly to safety in cases of grounding, collision, or other accident. Brunel proved in the *Great Eastern* that, with well-considered structural arrangements, iron could be used in vessels as large as any yet built. On the other hand, he would have greatly economised in weight had he been able to work with mild steel. In the remarkable developments in dimensions and speeds during the last twenty years mild steel has played an important part.

Aluminium, as remarked in the same address, has been much talked of for shipbuilding and engineering; trials have been made with it, or its alloys, in yachts, torpedo-boats, and small vessels; but, up to date, its use is exceedingly limited, and confined to other than structural work. Pure aluminium has not the strength or qualities required for ships' structures, although it has the great advantage of incorrodibility in sea-water and relative lightness. Most of the alloys of aluminium and copper which have been tried in shipbuilding have been found very liable to corrosion, and needing very careful painting to protect them. The American yacht *Defender*, which sailed against the *Valkyrie*, was built of this material, and rapidly corroded. In her construction, cost and durability were deliberately sacrificed to increase lightness and sail-power. Mr. Yarrow, with his usual enterprise, has also built vessels of this material, the most notable being a second-class torpedo-boat constructed in 1894 for the French Navy, 60 feet long and 20½ knots speed, weighing 10 tons complete. These boats had to be lifted and carried by depot ships, so that lightness was a great advantage. Mr. Yarrow estimated that the weight of hull was reduced one-half as compared with

steel, the saving in weight being 2½ tons. This boat also gave serious trouble from corrosion. No doubt, however, the production of alloys of sufficient strength and ductility, which shall be less liable to corrosion, is not beyond the powers of metallurgists. There can be no doubt that, if reasonable cost can be secured, aluminium alloys can be used with great advantage in parts of the ship not contributing in an important degree to the structural strength, internal partitions and casings, many fittings, and, above all, in the construction of the towering superstructures which, in modern passenger steamers, have grown to enormous dimensions, and are carried above the true "strength" deck, forming the upper flange of the girder. Large savings of weight are possible in this way, and when made aloft they greatly assist stability. In marine engines also aluminium alloys can be advantageously substituted for steel in many parts, especially moving parts. Shipbuilders and engineers will not fail to utilise these advantages if manufacturers can produce suitable materials at acceptable prices.

GERMANY has now forged ahead of Great Britain in the production of iron and steel. In 1903 the estimated production of pig-iron in Great Britain amounted to 8,350,000 tons. Germany in that year produced 10,085,634 tons. In 1903 Germany exported 3,480,000 tons of iron and steel, against 3,571,373 tons exported by Great Britain. In three items alone,—angles, blooms, and rails,—the German exports to the United Kingdom reached 607,649 tons in 1903.

FOURTEEN or fifteen years ago the matter of placing in underground conduits all the overhead wires that, with their supporting poles and cross-arms, were disfiguring the thoroughfares of many large cities, was a very vexed question, and in no other place was the matter so hotly contested as in the city of New York. In fact, it may be said that it was there that the battle was fought and won for underground conduits and cables. The chief opponent to placing the electrical wires underground in that city was one of the electric lighting companies, but that company doubtless represented and was backed by other electrical companies more or less equally interested from a financial standpont. It is, perhaps, not to be wondered at that these interests, especially the electric lighting interests, were opposed to placing their circuits in cables underground, since it meant an enormous outlay for the purchase of cables to displace the overhead wires, and at the time in question the electric light companies were fighting for every inch of ground gained from their principal competitors, the gas companies, and were at best not earning any too large dividends to suit their stockholders. Besides, not only was there to be considered by the electrical interests the first cost of underground cables and the sending of their overhead circuits to the junk pile, but there was also the annual rental for the ducts in which the cables were to be placed in the subways, the cost of which was about $900 per mile per annum for a three-inch duct. The use of the streets for poles and wires had cost nothing. The disfigurement of the streets by the poles and wires was, however, so pronounced, and the fatalities due to contact directly or indirectly with the overhead wires were so frequent and at times so abhorrent, that public opinion almost unanimously supported the authorities in this action in compelling the placing of the wires underground, and ultimately the electrical companies yielded to the inevitable. The alternative was to go out of business, as the civic authorities, after many delays and warnings, finally cut down the poles and removed the wires from the streets.

NOTWITHSTANDING the expense incurred in operating electrical circuits underground there were many compensating advantages, chief of which was

"THE CORNER HOUSE."

THE FIRST SOUTH AFRICAN "SKY SCRAPER." THE NEW BUILDING OF MESSRS. ECKSTEIN & CO., AT JOHANNESBURG, IS OF STEEL SKELETON CONSTRUCTION, 150 FEET HIGH

FROM A PHOTO BY GEO. A. WATSON, JOHANNESBURG

reliability of operation. With the overhead circuits there was never a storm, and, more particularly, never a sleet storm or a "blizzard," during and for days after which the city streets were not plunged in darkness, and as a result of which hundreds of miles of overhead wires were not completely crippled. Lightning storms also played havoc with the apparatus in the power houses, so that the approach of a severe storm by night or by day was a signal to those responsible for the operation of the circuits, wherever they might be, to prepare for the troubles which experience had shown was upon them. All this was changed with the burying of the wires, so that, apart from an occasional defect in an underground cable, the circuits operate uninterruptedly, day in and day out, totally regardless of weather conditions. Another frequent cause of serious delays in the operation of overhead wires in cities was the oc-

currence of fires, which very often necessitated the cutting of the wires. In contrast with this it may be noted that in the recent great fire in Baltimore the cables in the subways were quite uninjured, and a number of the through circuits in the conduits there have operated continuously, notwithstanding that tons of red-hot bricks were a few feet above them. In such a fire the poles and wires of an overhead system would have been utterly destroyed.

"SKY-SCRAPERS" and steel skeleton building construction have invaded even South Africa, and the first of the buildings of that type to be completed is shown on the opposite page, having been put up for the well-known Johannesburg firm of Eckstein & Co. While by no means so commanding in proportions as the host of tall office buildings in New York and Chicago, the Eckstein structure is a notable one in its surroundings, measuring 100 by 100 feet in area and rising to a height of 150 feet. With the exception of the foreman for the steel work, who was engaged in the United States, all the labour engaged on the structure was obtained locally. The building has nine stories and a basement, and the whole of the exterior, with the exception of the ground and first floors, is finished with Portland cement and stucco. Four passenger lifts and one freight lift, installed by the Otis Company, will serve the needs of the tenants. The light, heating, and power plant of the building is located in the basement.

AN effort is at present being made through a bill now pending in Congress to give the users of domestic alcohol for industrial purposes in this country the same exemption from internal revenue taxation that is granted in foreign countries. The enactment of this bill would provide an abundant supply of desirable internal combustion motor fuel, at a price as low as, if not lower than, the cost of gasoline. The benefits which would result from this legislation are so manifest that its adoption should be urged by every manufacturer or user of automobiles, power launches, or motor engines of any kind. The measure has absolutely no connection with the question of the importation of foreign alcohol. It is not intended to interfere in any way with the present duty on imported alcohol. The material which it is proposed to free from the present excessive internal revenue tax is alcohol made in this country from materials grown by our farmers, which has been rendered unfit for use as a beverage. The chief obstacle to the enactment of this bill is the opposition of the wood alcohol interests, who are now enabled to sell their inferior product at a large profit by reason of the fact that it is not taxed. These interests are antagonising the bill on the ground that their industry will be injured by its enactment. In other words, they ask Congress to continue a tax of $2.08 per gallon of commercial alcohol on the product of corn raised by our farmers when used for industrial purposes, while allowing their product, used for exactly the same purpose, to go untaxed. A special reason why the plea of the wood alcohol interests for the continuance of the tax on domestic ethyl alcohol should not be regarded is the fact that large areas of forest are destroyed in the process of manufacturing the eight or ten million gallons of wood alcohol now used annually. Certainly there would seem to be no justification for a policy which encourages the wasteful destruction of forests for use in producing a substance which is greatly inferior to, and much dearer than, a similar substance procurable in unlimited quantities from corn, potatoes, and other farm products.

WRITING on the responsibility of the engineer aboard the modern ship of war in the *Journal* of the American Society of Naval Engineers, Lieutenant C. N. Offley, U. S. N., says:—"It is a military maxim that the morale of a regiment is judged by the soldierly bearing

and gallantry of the field officers, and the efficiency of the enlisted personnel of the battleship is but a reflection of the manner in which duty is performed by her commanding officer and the commissioned personnel. Particularly, however, does the engineer force of a war vessel follow the example set by the chief engineer. Even the title of this officer is presumptive evidence that he should keep in close touch with those serving under him. Where unusual service is performed in the engine room it is certain that the chief engineer of the ship has been the principal personage in bringing about this efficiency. One need have but little sea service to appreciate the fact that demoralisation in the engine room will soon dispirit an entire ship's company. Failure in the engine room simply keeps the vessel from performing her assigned duty. It is not the propelling engines alone which are dependent upon the efficiency of the chief engineer. While there are pneumatic, hydraulic and electric appliances under the supervision and control of other officers, all these machines are primarily operated by steam. Steam is thus the primary agency whereby the ship is steered, the anchor raised, the great guns operated and loaded. Even the ventilation and the illumination of the various compartments is dependent upon the efficiency of the boilers. The boilers are the lungs of the vessel, and where there is impairment in this direction the resultant is inefficiency of various auxiliary appliances. The non-commissioned officers supervising the work in both engine and fire rooms should not only possess considerable mechanical skill and powers of endurance, but there must be readiness of resource, quickness of action and aptitude for the work. A lever turned the wrong way may cause the ship to go in the direction opposite from what was intended, and a collision may be the ultimate consequence of such an error. The man without courage, steadiness of purpose and coolness in emergency will soon succumb to the strain of work in the engine room of a warship. The fact that there can be seldom found in the engine rooms of the ocean greyhounds a gray-haired chief engineer shows that the strain and responsibility is of a severe nature, and that the pace of the work is one that kills."

In spite of many legal impediments in the way of electric light and power enterprise in Great Britain, substantial progress has been made along both lines of undertaking. In his recent inaugural address before the Institution of Electrical Engineers, President Robert Kaye Gray told that, exclusive of traction motors, in March of last year, lamps and motors equivalent to over 14,000,000 eight-candle-power lamps were connected to the mains of public electricity supply undertakings, London being represented to the extent of about 5,000,000. There were about 300 towns enjoying the advantage of an electricity supply, this number including, with two exceptions, all the towns whose population exceeds 100,000. The exceptions were Tottenham and the Rhondda district, which did not seem anxious to be alongside of their thirty-eight fellows. It appears that at this period, exclusive of power companies, the public supply stations had motors amounting to 55,000 H. P. connected to their mains. Municipal undertakings own generating plant of a rated capacity of 320,000 kilowatts, and private undertakings are represented by 160,000. In London the companies are proprietors of about 100,000 kilowatts, whereas the public bodies are responsible for approximately 28,000. The pre-eminence of the companies in London is due to the fact that they acted as the pioneers and were first in the field. The average rated capacity of a British station appears to be about 1400 kilowatts. It is to be remarked that while in the provinces the average municipal station has a capacity of nearly three times that of a company station, in the metropolis the ratio is reversed. Again, the average metropolitan company has, approximately, ten times the plant capacity of the average provincial company.

It is interesting to learn further from President Gray's address that present tendencies in Great Britain are decidedly in favour of the direct-current system with a three-wire distribution; the number of direct-current undertakings increased from 139 in 1901 to 214 in 1902 and 260 in 1903. For these three years the alternating-current stations numbered 67, 68 and 69, respectively. There are now established in Great Britain 13 two-phase and 5 three-phase stations, exclusive of power-transmission stations. In 29 cases supply is given on two or even more systems. Many of the alternating-current stations have taken up the supply of direct-current, others have added two-phase or three-phase supply to their single-phase service, or have changed over completely to one of these. The direct-current system appears to be in no immediate danger of supersession, in part owing to the raising of the voltage, and the consequent possible extension of the service area. The number of voltages in use is somewhat confusing, and presents to the Standards Committee a difficult problem to solve. These voltages now amount to about 16, and out of 289 examples of tressures nearly one-third are declared at 230, more than one-sixth are given as 220, while voltages of 240, 200 and 100 claim about one-eighth each. There are between fifty and sixty stations which revel in more than one declared pressure. The extent to which the change from one voltage to another has taken place may be judged from the fact that in 234 cases the pressure is upwards of 200 volts; 64 supply current both above and below 200, and there are only 29 whose supply is entirely under 200 volts.

B. H. WARREN,

THE NEW PRESIDENT OF THE ALLIS–CHALMERS COMPANY, CHICAGO

BEHIND all great industrial successes, and more or less hidden from the popular view, is the great organiser, the administrator, the man who makes and guides the machinery of business. Mr. B. H. Warren is one of these men, and his record is known well enough in industrial circles, although the general public may be unfamiliar with it.

To Mr. Warren has been given the responsible task of bringing together the several companies controlled by the Allis-Chalmers Company, of Chicago, and working them under the Allis-Chalmers name as a unit, as an harmonious whole. But he has borne heavy responsibilities before, and has carried them through to conspicuous success. He was for six years with the Westinghouse Electric & Manufacturing Company, and, as second vice-president of that immense concern, was responsible for its manufacturing and commercial organisation, for its producing and its selling ends.

Mr. Warren is a Boston man, and an ex-naval engineer officer. It is worth noting how our great industries come to rely upon our naval engineers, enticing them from the Service, and enrolling them among the chiefs of staff of the captains of industry. They even become captains of industry themselves. Mr. George Westinghouse is the most notable instance. He was a naval engineer during the Civil War.

Mr. Warren graduated from the Naval Academy at Annapolis in 1874. After that he had four years of active service. Then he went into business, as mechanical engineer of the Hancock Inspirator Company, of Boston. Later he went to Europe to handle their foreign business, and after four years abroad he returned to Boston and took charge of the company's new works.

From 1890 to 1895 he managed the

hoisting machinery and pulley block department of the Yale & Towne Manufacturing Company, of Stamford, Conn., and then he became assistant secretary and treasurer of the Pratt & Whitney Company, of Hartford. Then Mr. Westinghouse invited him to Pittsburgh, and there he stayed six years. First, he was made general manager of the Westinghouse Electric Works. Within a year he had saved the company so much money and had so largely increased the output of the works that Mr. Westinghouse made him second vice-president. When Mr. Lemuel Bannister went abroad a few months later to establish Westinghouse organisations in Europe, Mr. Warren was placed in full charge of the commercial end of the company's business, in addition to continuing his duties as the head of the manufacturing branch. The task was a great one, but he carried it with complete success.

Mr. Warren left the Westinghouse Company two years ago. Now he goes to the Allis-Chalmers Company, with headquarters in New York, and with full administrative authority over the many ramifications of their business, their works in Milwaukee, Chicago, Cincinnati and Scranton, and their selling force in all its branches. What he will do can be safely inferred from what he has done.

Mr. Warren is a member of the American Society of Mechanical Engineers, of which he is also an ex-vice-president, of the Society of Naval Engineers, of the Society of Naval Architects and Marine Engineers, and of the University and Engineers clubs, of New York.

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THE DEVELOPMENT OF ELECTRIC POWER TRANSMISSION

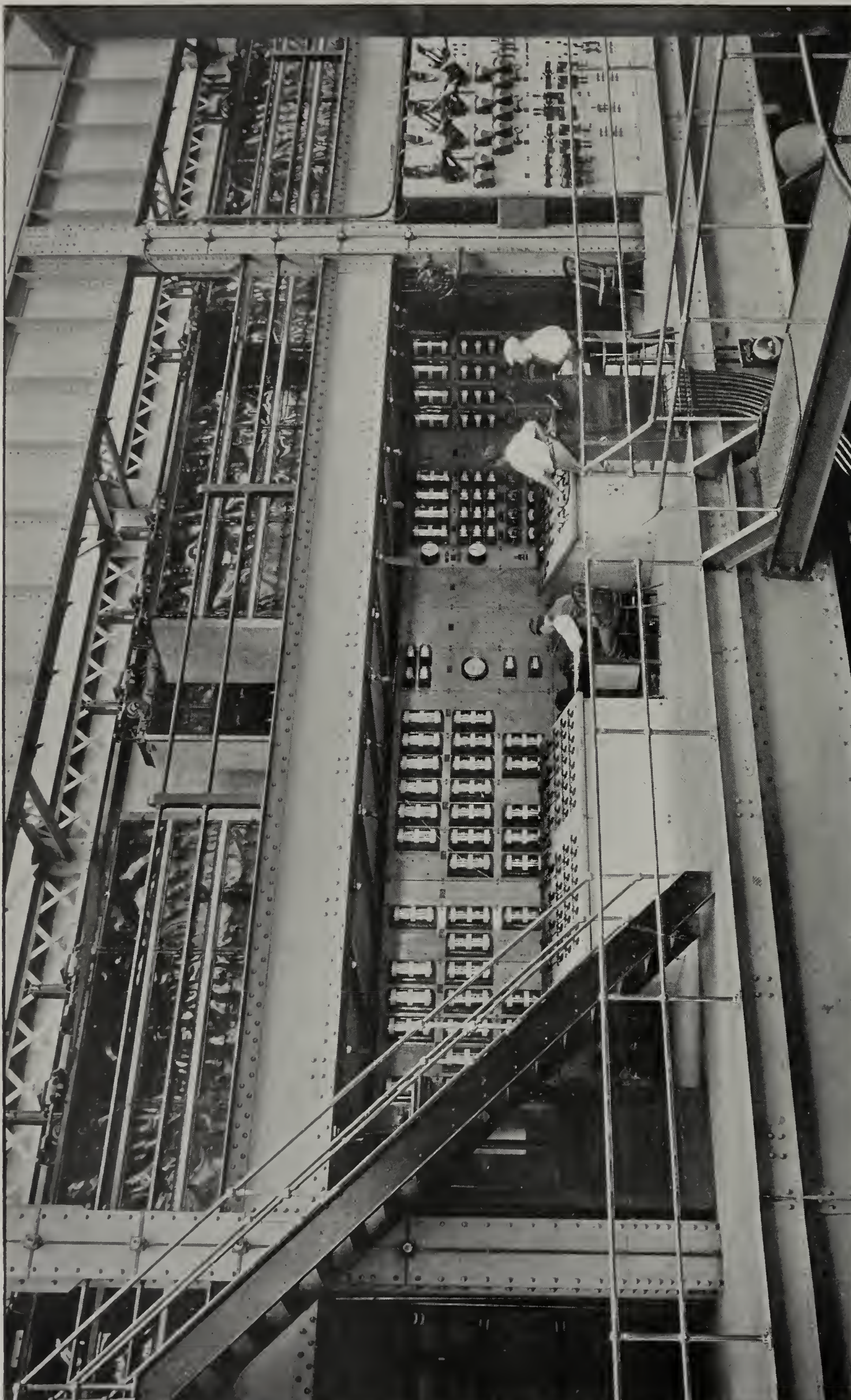
By Lewis Buckley Stillwell

IN October, 1886, in a small room on the top floor of an old house in Pittsburgh, Pa., three hundred incandescent lamps were lighted continuously for a period of about two weeks by alternating current, transmitted a distance slightly exceeding two miles, over a single-phase circuit, comprising two copper wires of No. 4 B. & S. gauge. The potential used was 1000 volts, the frequency about 130 cycles per second, and the lamps were connected in parallel to the secondary circuits of half a dozen transformers. The ratio of transformation was 1000 to 50.

This was the first instance, in America at least, in which alternating current was used in transmitting electric energy beyond laboratory distances for the supply of translating devices connected in multiple arc. The alternator used to supply the power was driven by belt from a line shaft, to which a high-speed automatic engine was connected, and this generating plant was located in a shop of the Westinghouse Electric & Manufacturing Company on the banks of the Allegheny River within a mile of the site of old Fort Duquesne.

It was the writer's fortune to be detailed to watch those lamps during twelve hours out of every twenty-four during the test,—his first practical experience in applied electricity,—and he vividly recalls the keen interest with which everybody who had anything to do with the work observed the results. In the history of American industrial progress the Lawrenceville test, as it has been called, was an event of no little importance. To Stanley and Shallenberger, for the technical skill and for the patient work which produced the apparatus, and to George Westinghouse, whose far-sighted enterprise realised possibilities at that time scouted by others, all those who now are deriving benefit from the wonderfully extended use of alternating currents are under an obligation which they should be glad to recognise.

Prior to the Lawrenceville test, distribution of electric energy to lamps or motors had been accomplished by continuous-current systems operating at potentials of 110 to 220 volts. The



OPERATING AND INSTRUMENT BOARD OF THE MANHATTAN RAILWAY COMPANY, NEW YORK

TABLE I.—AMERICAN CENTRAL ELECTRIC STATIONS IN 1902

Items	Total	Private Stations	Municipal Stations
Number of stations	3,620	2,805	815
Cost of construction and equipment	$504,740,352	$482,719,879	$22,020,473
Earnings from operation	84,186,605	77,349,749	*6,836,856
Income from all other sources	1,514,000	1,385,751	128,249
Gross income	85,700,605	78,735,500	6,965,105
Total expenses	68,081,375	62,835,388	5,245,987
Salaried officials and clerks—			
Average number	6,996	6,046	950
Salaries	$5,663,580	$5,206,199	$457,381
Wage-earners—			
Average number	23,330	20,863	2,467
Wages	$14,983,112	$13,560,771	$1,422,341
Power plant equipment—			
Steam engines—			
Number	5,930	4,870	1,060
Horse-power	1,379,941	1,232,923	147,018
Water-wheels—			
Number	1,390	1,308	82
Horse-power	438,472	427,254	11,218
Generating plant equipment—			
Dynamos—			
Direct current, constant voltage—			
Number	3,823	3,405	418
Horse-power	442,446	418,913	23,533
Direct current, constant amperage—			
Number	3,539	2,957	582
Horse-power	195,531	157,768	37,763
Alternating and polyphase current—			
Number	5,122	4,300	822
Horse-power	987,003	896,315	90,688
Output of stations—			
Kilowatt hours, total for year	2,453,502,652	2,257,598,213	195,906,439
Total number of arc lamps	385,698	334,903	50,795
Total number of incandescent lamps	18,194,044	16,616,593	1,577,451

* Includes estimated income from public service.

three-wire system invented by Edison, permitting the use of a potential of 220 volts, was coming into use for general purposes in the larger cities, and was regarded as the highest potential available for such work. The general significance of the results of the Lawrenceville test was keenly realised; but the difficulties encountered in attempting to develop single-phase, alternating-current motors, capable of operation at the high frequency then used, practically prevented for a number of years the use of alternating current for power purposes. It was, however, rapidly developed and extensively applied in the field of incandescent lighting.

Tesla patented the polyphase alternating-current motor in 1888, but this also was slow in development, owing largely to the fact that for a long time in America efforts were principally directed toward the development of a motor adapted to the high frequency of 130 cycles per second. In 1890 the Westinghouse Company adopted as standards two lower frequencies,—60 cycles per second and 30 cycles per second. The step facilitated greatly the development of satisfactory polyphase motors, and not long afterward they began to come into commercial use.

The commercial significance of the Lawrenceville test is strikingly illustrated—although the impression conveyed by the illustration is a somewhat exaggerated one—by the story of the manager of a gold mine in Colorado, who, in 1896, was able to operate a stamp mill located at a distance of about three miles from his water-power by alternating current transmitted to the motor over a circuit consisting of iron telephone wire of ordinary size. This was accomplished by using a high-potential single-phase alternating current. The cost of the telephone wire was about sixty dollars. It is stated that an estimate for a continuous-current plant to do the same work had been submitted by a manufacturer of continuous-current machinery, and that these plans called for the installation of copper circuits costing more than sixty thousand dollars.

United States Census Bulletin No. 5, recently issued, places us for the first time in possession of many important and extremely interesting statistical facts relating to the use of electricity for light

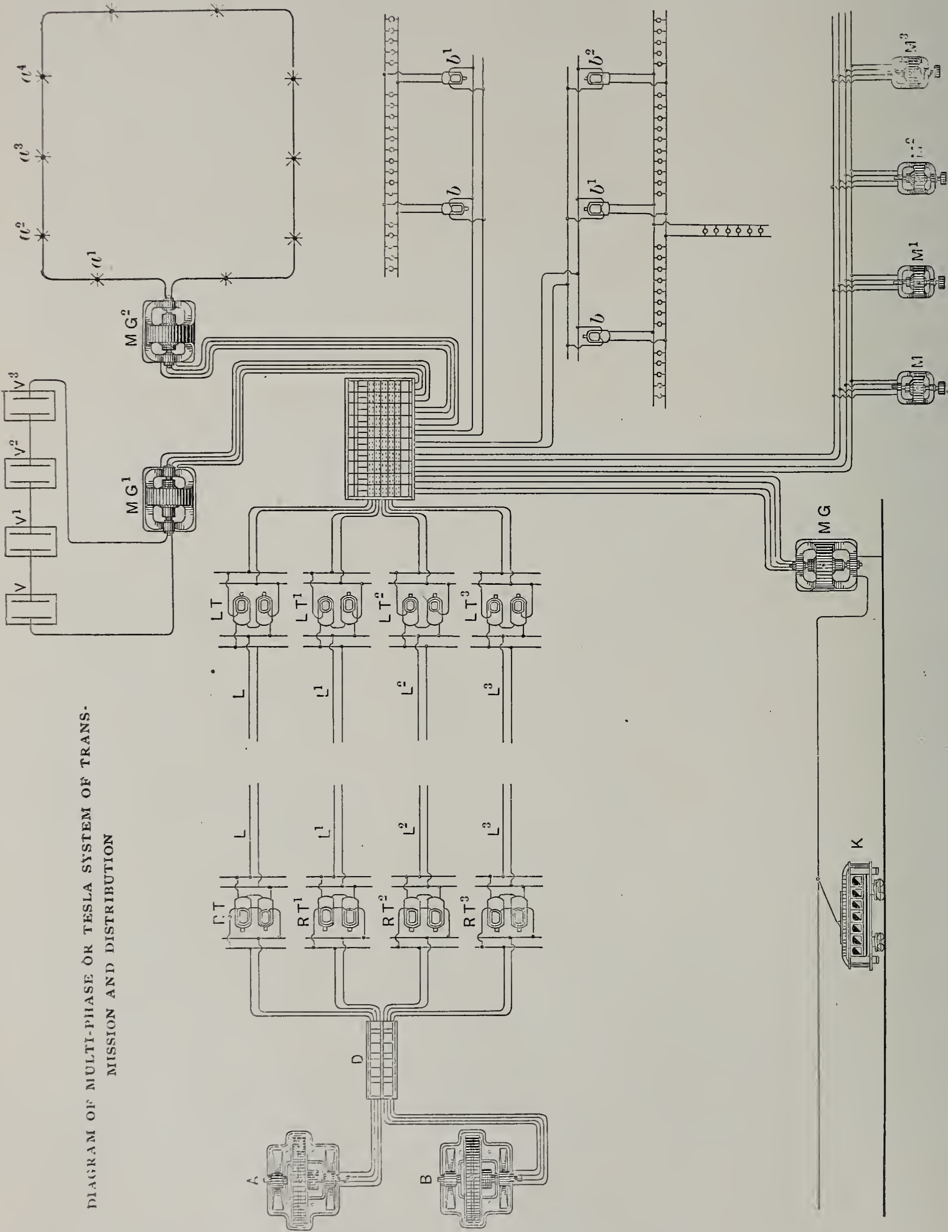


DIAGRAM OF MULTI-PHASE OR TESLA SYSTEM OF TRANSMISSION AND DISTRIBUTION

and power purposes in the United States exclusive of its use for traction purposes. Table I. of this bulletin cannot be improved by further condensation, and is, therefore, here reproduced.

It will be noted that of the aggregate output of dynamos installed in central stations which supply power exclusively for lighting and power purposes, which aggregate amounts to 1,624,480 horse-power, the rated output of alternating-current dynamos constitutes more than 60 per cent. A considerable number of electric power plants, installed primarily for the purpose of operating street and electric railways, also supply current for lighting and power purposes, and if these be added to those which furnish power for lighting and power purposes only, the grand aggregate of central stations becomes 3738, the number of arc lamps 419,561, the number of incandescent lamps 19,636,729, and the total income from the sale of current $90,458,420.

The relative commercial importance of the central electric station industry and gas industry is shown in Table II., which also is reproduced from Census Bulletin No. 5.

TABLE II.—COMPARATIVE SUMMARY OF AMERICAN CENTRAL ELECTRIC STATIONS AND GAS PLANTS

Items	Central Electric Stations, 1902	Gas Plants, 1,900
Number of establishments	3,620	877
Cost of construction and equipment	$504,740 352	*$567,000,506
Cost of supplies, material and fuel	22 915,932	$20,605,356
Salaried officials and clerks—		
Average number	6,996	5,904
Salaries	$5,663,580	$5,273,500
Wage-earners—		
Average number	23,330	22,459
Wages	$14 983,112	$12,436,296
Income	85,700,605	†75,716,693

* Capital. † Value of products.

The peculiar value of alternating-current development resulting from the reduction in cost of distribution which is effected by this class of apparatus is illustrated by the fact that 75 per cent. of the central electric stations are in towns of less than 5000 inhabitants, as compared with 22.8 per cent. of the gas plants.

As regards stationary motors, the aggregate number installed is 101,064, and their aggregate horse-power amounts to 624,686. The total rated horse-power of steam engines and water-wheels used to drive dynamos is 1,772,-813, of which total 77.8 per cent. are the indicated capacity of steam engines and 22.2 per cent. the stated capacity of water-wheels.

TABLE III.—PERCENTAGES THAT THE NUMBER AND HORSE-POWER OF THE DIFFERENT VARIETIES OF DYNAMOS ARE OF THE TOTAL STATIONS IN 1902

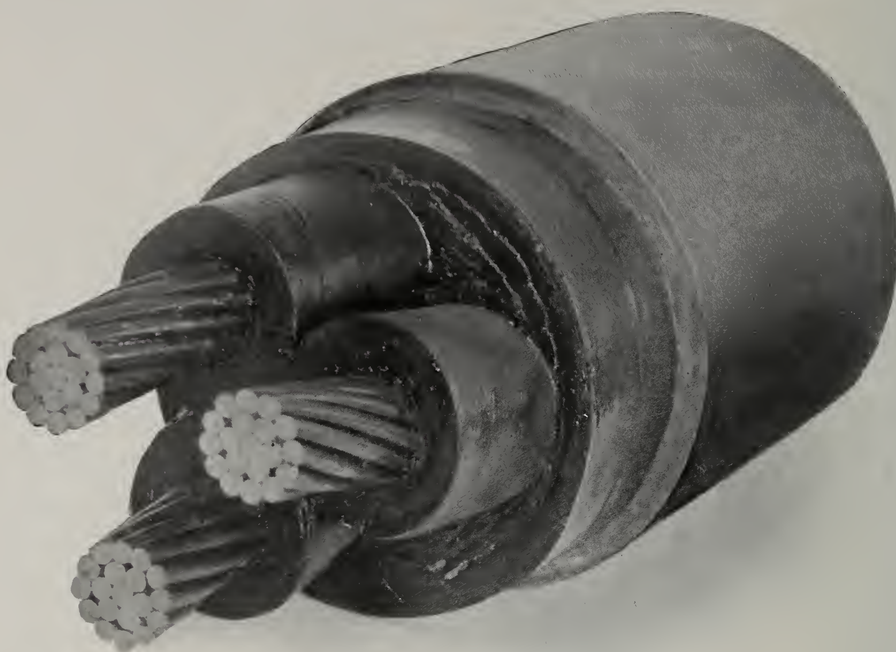
Kind of Dynamo	Total
Total—	
Number	100 0
Horse-power	100.0
Direct-current, constant voltage—	
Number	30.6
Horse-power	27.2
Direct-current, constant amperage—	
Number	28.3
Horse-power	12 0
Alternating and polyphase current—	
Number	41.0
Horse-power	60.8

The relative number of dynamos and relative aggregate horse-power of alternators, as compared with direct-current, constant voltage machines and direct-current, constant ampèrage machines, are shown in Table III.

It will be noted that the average alternator is a much larger machine than the average direct-current machine of either of the two direct-current classes.

It is impracticable within the limits of this article to attempt anything like a comprehensive review of the development of alternating-current apparatus for transmission and distribution of power which shall refer even briefly to the many small steps which, in the aggregate, have contributed so much to the march of progress; but in brief retrospect reference to a few of the more important steps may serve to emphasise the remarkable rapidity which has characterised the evolution of this comparatively young, but very vigorous, addition to present industrial assets.

In 1890 the celebrated Frankfort-Lauffen transmission illustrated and emphasised the possibilities of high-potential alternating current in bridging great distances. The potential used during the test was at times 14,000 volts, and at other times 28,000 volts; the distance was 110 miles; the amount of power was small,—about 200 H. P. The transmission was in no sense a commercial success, nor, indeed, was it expected to be. It served its purpose, however, of demonstrating, upon a scale sufficiently large, the possibility of insulating a long circuit effectively for potentials very high as compared with anything previously attempted, and it also served the purpose of concentrating attention in many quarters upon the subject of electric power transmission, and so contributed in a striking and effective manner to the commercial development of a relatively new art.



A FULL-SIZE SECTION OF THREE-CONDUCTOR, PAPER-INSULATED CABLE FOR 11,000 VOLT THREE-PHASE TRANSMISSION USED BY THE INTERBOROUGH RAPID TRANSIT CO., NEW YORK

In America the first important attempt at transmitting power for commercial purposes at a potential materially exceeding the 3000 volts used at Telluride, Colorado, in 1890, was the installation of the plant at San Bernardino and Pomona, in Southern California. The potential used was 10,000 volts; the distance from the water-power to San Bernardino was twenty-nine miles.

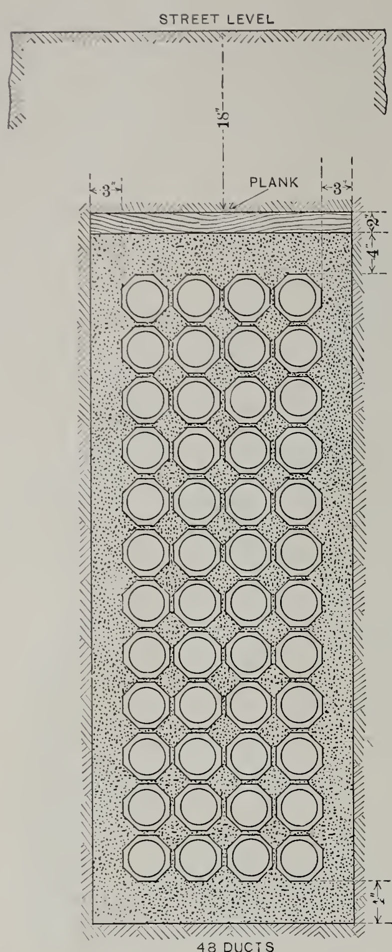
On May 2, 1893, Mr. George H. Winslow, engineer in charge of the plant, connected the Pomona circuit in series with that to San Bernardino and transmitted about 100 E. H. P. to San Bernardino, a distance of forty-two and one-half miles, this being by far the greatest distance attained in America up to that time.

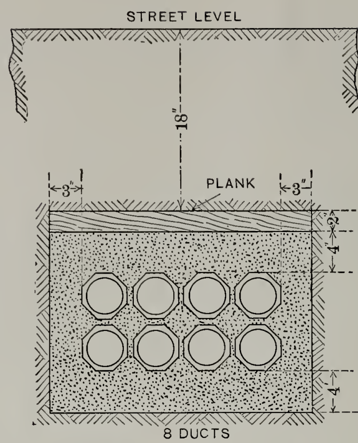
About that time, in various shops and laboratories of America and Europe, the polyphase motor was fast taking commercial form, and at the Chicago Exposition of 1893 some striking and important exhibits of polyphase apparatus were shown in operation. Among these was a complete power transmission

plant, comprising a 375-KW, two-phase alternator, an outfit of step-up and step-down transformers connected by a high-potential circuit, a 375-KW rotary converter delivering continuous current at 550 volts, a 60 H. P. synchronous motor, and a number of induction motors, ranging from 1 H. P. to 15 H. P. The system was two-phase, the frequency 30 cycles per second, and the potential of the transmission circuit 10,000 volts. At the receiving end of the line incandescent lamps were supplied through transformers, and arc lamps were fed by continuous current from the rotary converter. Continuous current from the rotary converter was also used to operate direct-current motors. The diagram on page 100, which is reproduced from a descriptive circular published at the time, shows that this plant embodied all essential features of the latest transmission plants, except that two-phase circuits were employed instead of the three-phase plan now generally preferred. The Germans were first to perceive clearly the advantages of the three-phase system, as compared with the two-phase system, and to push the development of three-phase apparatus. Dobrovolski showed me, in Berlin, in 1890,—possibly as early as 1889,—a three-phase motor probably capable of developing a quarter of a horse-power. In America, Bell, of the General Electric Company, installed the first three-phase plant at Redlands, in California, in 1893.

FULL SIZE RUBBER-INSULATED, STEEL-ARMOURED, THREE-CONDUCTOR CABLE FOR SUBMARINE WORK, USED BY THE INTERBOROUGH RAPID TRANSIT COMPANY OF NEW YORK, UNDERNEATH HARLEM RIVER

From the autumn of 1892, to October, 1893, the officers and engineers of the Cataract Construction Company were systematically working toward a





CROSS-SECTION OF 48-DUCT AND OF 8 DUCT CABLE CONDUITS

decision of the great engineering question of the best method of utilising the power of Niagara, and in the month last mentioned they executed a contract for polyphase alternating-current machinery to be installed in a central station and utilised in generating electricity to be distributed for power and lighting purposes. The decision of the Cataract Company, which had studied the subject exhaustively, both in Europe and America, had a notably stimulating effect, and less than two years later, in the Niagara power number of CASSIER'S MAGAZINE, issued in July, 1895, the late S. Dana Greene, in a very interesting article upon "Distribution of Niagara Energy," was able to list not less than seventy electric transmission plants in America in operation or under construction.

To my mind, the most important events in connection with the evolution of electric transmission in America are (1) the Lawrenceville test of 1886, by which the commercial practicability of the constant-potential transformer,—the key to high-potential transmission,—was demonstrated; (2) the invention of the polyphase motor, patented by Nikola Tesla in 1888; and (3) the adoption, in 1893, of the polyphase alternating-current, constant-potential system as the means of distributing power from Niagara Falls.

The Lawrenceville test demonstrated the possibilities of the transformer in reducing the cost of transmitting circuits; the invention of the polyphase motor furnished the means of utilising the transmitted power for power purposes, and the adoption of polyphase alternating currents by the Cataract Construction Company for the great work at Niagara Falls sealed the commercial success of the system. An excellent meter for alternating currents had been invented and perfected by Shallenberger as early as 1888, and Elihu Thomson also had produced an effective meter for the same kind of service.

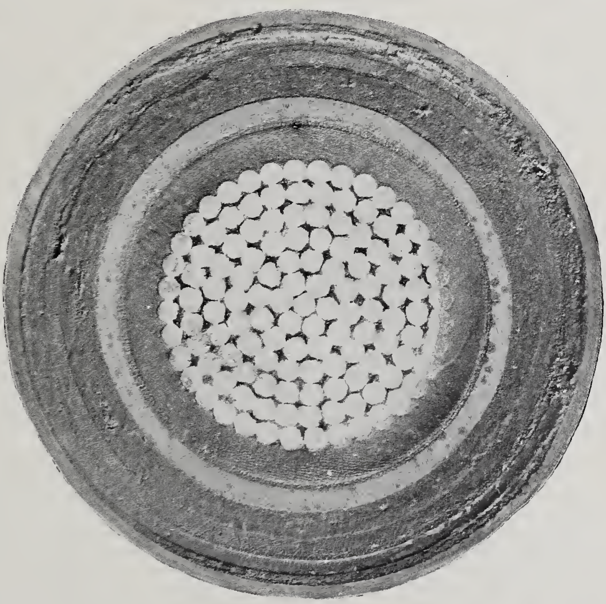
But the invention of the transformer,

the motor, and the meter left still to be developed much apparatus of prime importance in the construction of the complete and effective plant for transmission and distribution of power by electricity. Switches, operated automatically or otherwise, and adapted to high-potential circuits; insulators for overhead lines and insulation for underground cables; devices for protecting apparatus against the effects of lightning,—all these and other adjuncts, now deemed essential, were still in the future in 1893 so far as heavy power circuits carrying high potentials were concerned, and still in the future also was the question how best to aggregate the complicated apparatus of a transmission system,—one of the great questions of engineering practice which still receives answers varying in respect to important details, but varying far less than they did ten years ago. There remained also the training of men and the development of effective organisations for operation,—a work in itself requiring time, thought, and painstaking effort.

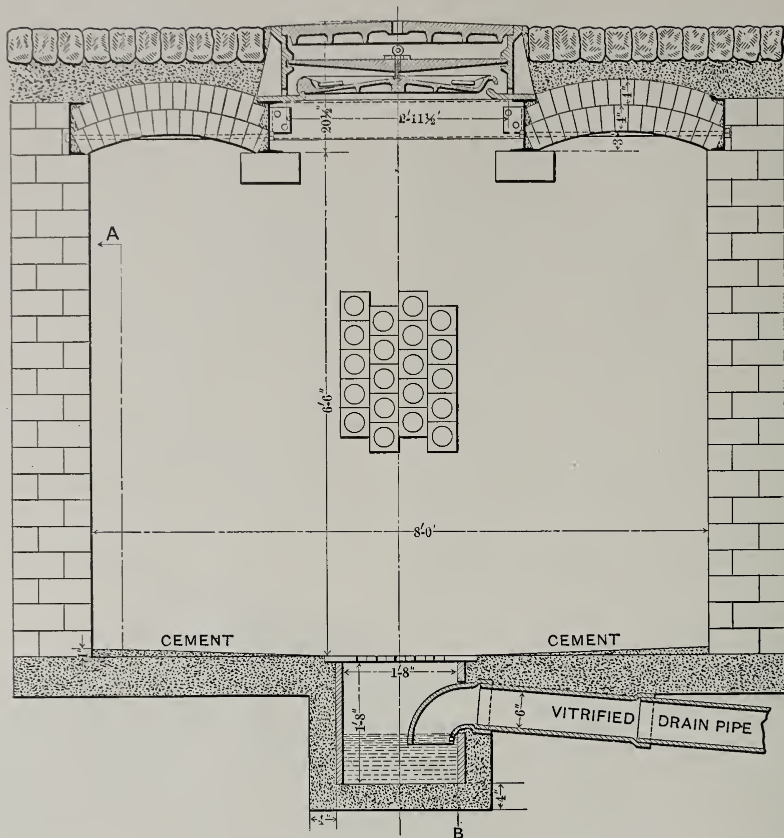
Thanks to Hopkinson, Kapp, Schmid, Brown and others, the art of dynamo design had been developed to a point where it became possible to predetermine the constants of a dynamo, and to design and build in full confidence that the results attained under test would coincide with expectation based upon calculations. The transformer, the motor and the meter placed us in possession of means for delivering and measuring power at a distance; but, as has been indicated, much remained to be done in the development of a reliable system.

It should be noted also that the development of apparatus for electric transmission thus far has been effected necessarily not with reference to fixed ultimate conditions, but with reference to conditions which are constantly changing by reason of the demand for higher and still higher potentials, and by reason of the increased complexity of circuits which results from the growth of existing plants. As the possibility of bringing greater distances becomes apparent, the demand for increased potentials makes itself felt, and every important increase of potential implies corresponding increase in insulation of circuits, including transformers, switches and all devices connected therewith.

Again, as a given power company extends the sale of its product, every additional user of power implies additional apparatus connected to the circuits and increased risk of interruption of the general supply of power to customers of the company. Increase of potential must be met by improvement in insulation, and interruptions due to aggregate length and complexity of an interconnected system of conductors must be met by improvement in automatic circuit-breaking devices, arranged with reference to the location of interruptions of service due to failure of insulation or



RUBBER INSULATED, STEEL ARMOURED, SINGLE-CONDUCTOR CABLE FOR SUBMARINE WORK, AS USED BY THE INTERBOROUGH RAPID TRANSIT CO., OF NEW YORK



CROSS SECTION OF A CABLE MANHOLE OF THE MANHATTAN DIVISION OF THE INTERBOROUGH RAPID TRANSIT COMPANY, OF NEW YORK

other causes. The fact that during the past ten years the rate of interest upon capital has been decreasing in America has, doubtless, tended to lessen in some degree the force of the argument in favour of a rapid increase in potentials adopted for new plants; but the reasoning which is brought to bear upon such questions as the selection of potential too often has little connection, or at least little conscious connection, with such matters as a progressive fall in rates of interest.

A subject that has received less attention than it deserves is the difficulty of maintaining an uninterrupted supply of power to the motors, lamps, and other translating devices used by customers which results from increased lengths of conductors and increased numbers of translating devices connected to a single source of supply. Electrical engineers are not accustomed to enlarge upon the subject of interruptions of service, but the first step in the correction of defects is recognition of their existence, and reference to this phase of the general subject may be useful.

Obviously, interruptions of service may have their origin in the power plant, in the transmitting circuits, or in apparatus located upon the premises of the user. Other things being equal, those due to line troubles will vary with the length of the line, as has been clearly recognised since the earliest days of transmission. Equally obvious, but apparently less clearly recognised, is the fact that a plant delivering power to a dozen users over a line of equal length faces an increased risk of interruption of service by reason of the addi-

tion of a number of branch circuits at the receiving end of the line, and connection to the system of a dozen outfits of apparatus in users' premises in place of one. Where it happens necessarily, as at Buffalo, at Milan, and at a few other places, that a very considerable number of users are supplied through cables placed underground, which cables, in turn, receive through transforming stations their supply from overhead transmitting circuits extending across country from the water-power, the difficulties in the way of maintaining an uninterrupted supply of power become very serious.

Imagine, if you please, that in a given city a score of separate steam engines are used to drive line shafts in twenty factories and mills. Each of these engines is liable to a certain number of accidental interruptions of service, averaging, perhaps, one per annum. If, for the twenty steam plants, twenty electric motors, supplied through an inter-connected system of conductors, be substituted, it is evident that effective means must be adopted to prevent an accident to one motor, resulting in interruption of service in the twenty factories and mills; otherwise if accidents causing interruption average the same with motors as with steam plants, each user will suffer from twenty interruptions per annum instead of from one.

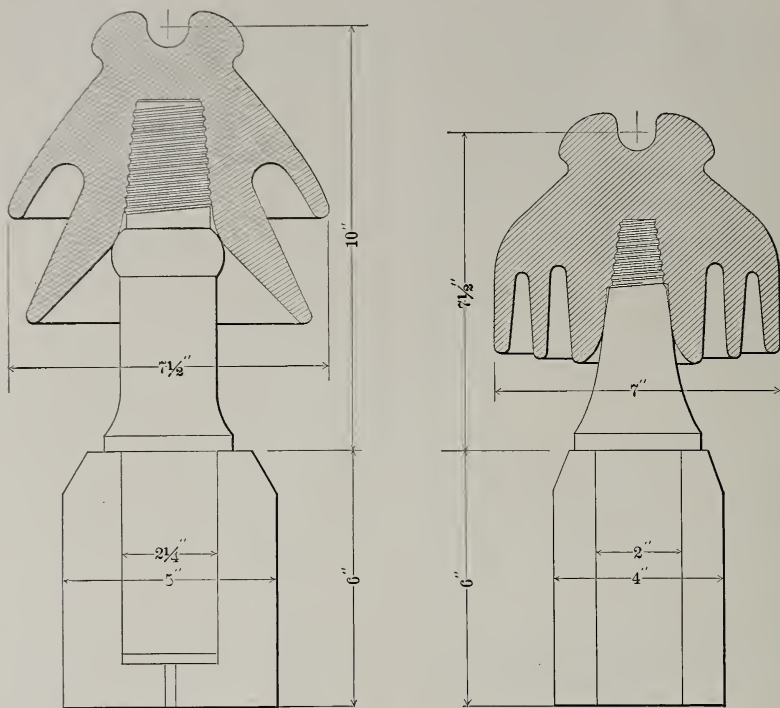
It may be noted still further that the user who philosophically bears with an interruption caused by apparatus owned by himself is usually far from philosophical when inconvenienced by interruptions of service due primarily to failure of other people's machinery. The reasons for adopting effective means for preventing interruptions of service, therefore, increase in a ratio greater than the increase in number of users.

Unfortunately, the complete solution of the problem cannot be found in the adoption of the fuse or safety-link, which is generally and satisfactorily used in dealing with the similar problem which arises in supplying lamps and motors connected to the great direct-current networks in the large cities, since in such cases as that of Buffalo the distances involved in the local distribution are so great as to make the use of high-potential circuits to more than one transforming station imperative, and with circuits conveying alternating currents at 10,000 volts or even at 2000 volts ordinary fuse strips are altogether inapplicable, while nine-tenths of the special devices which have been proposed to take their place are equally useless.

The problem is made still more difficult by the phenomena of resonance and so-called electric surging, the latter of which always follows a sudden disturbance of potential of the system, while the former, under certain conditions of capacity, inductance, and frequency, is liable to develop potentials capable of breaking down the most perfect insulation available at the present time. Obviously here is a fine opportunity for the exercise of skill, sound judgment, and perhaps even inventive ability upon the part of the engineer who lays out a system of high-potential alternating-current distribution destined to supply power at some future time, if not at the outstart, to a large number of users distributed over territory too extensive to be reached by direct current.

The first thing to be done is, of course, to secure throughout the system the most perfect insulation that is practicable. Could the insulation be maintained perfect in all parts, nothing more would be needed. This, unfortunately, is not the case, and it becomes necessary, therefore, to lay out such a system of distribution with the greatest possible care, adopting effective means for localising the interruption which can result from a failure of insulation in any part of the system.

Much has been done since 1893 to overcome the difficulties faced by the companies which first ventured into the field of polyphase transmission and distribution, but there is still room for material improvement. The insulation of cables has made wonderful progress, as have also glass and porcelain insulators for overhead lines, although the quality of American porcelain is not yet equal



TYPE C AND TYPE E INSULATORS USED BY THE NIAGARA FALLS POWER COMPANY

to that of European porcelain used for the same purpose.

The time-limit circuit-breaker, intelligently applied, is of great value in lessening the evil consequence of failure of insulation by localising the resultant interruption of service; but the reversed current circuit-breaker, first used by Andrews, at Hastings, England, which should be an equally valuable adjunct to a transmission plant, is not yet available in thoroughly satisfactory form. The extraordinary development of the oil switch in recent years in America, following, but quickly surpassing, European practice, has furnished an effective solution to many of the vexing questions of switchboard practice which caused so much trouble a few years ago. The insulation of dynamos to-day is such that the generation of currents at 11,000 volts is effected with a factor of safety equal to what was possible ten years ago with generated potentials of 2200 volts, and the advance in construction of transformers is almost equally striking.

In large plants the general adoption of the method of operating switches in the power circuits at a distance from the operator by means of compressed air or electricity, insuring safety of the operator, has resulted in great gain in certainty of operation. To this end also have contributed a number of valuable auxiliary devices, such as the ingenious and effective synchronism indicator invented by Mr. Paul M. Lincoln, the diagrammatic arrangement of control switches, which places under the eye of the operator at all times an accurate diagram of connections existing throughout the system, various improvements in regulating and governing mechanism of engines, and more particularly of hydraulic turbines, and, most important of all, perhaps, the development of devices for the protection of electric apparatus against the effects of atmospheric electricity.

It may be interesting to refer briefly to some of the more important of these improvements of the last decade. As

regards means available for transmission, the most striking development is the rapid evolution of cables insulated by paper, treated with resinous oils.

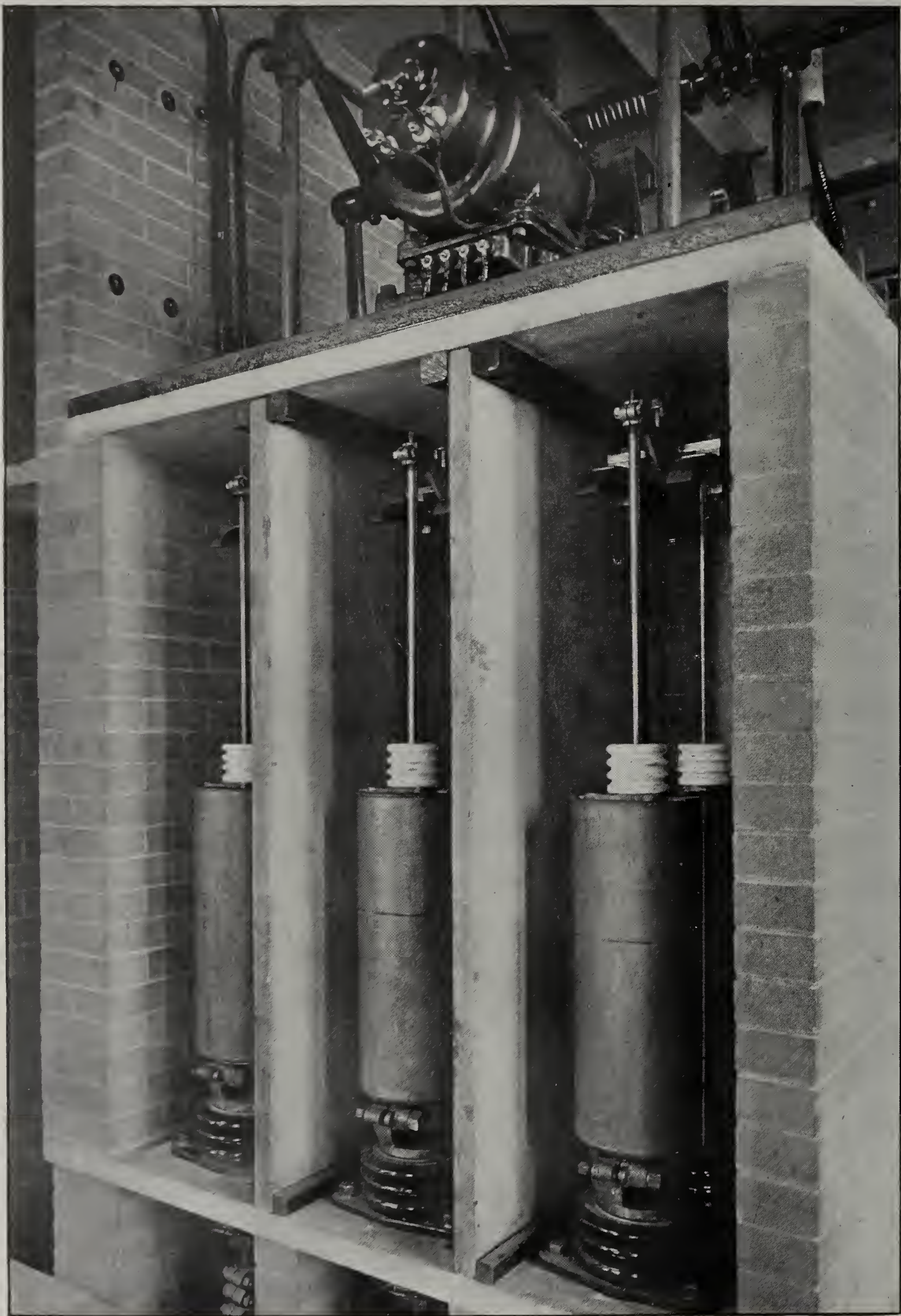
They are necessarily lead-sheathed to protect the insulation against moisture, and if the sheath be preserved and the cables be not operated at temperatures exceeding 80 C. degrees, there appears to be no reason to doubt their durability. In the city of New York, the Manhattan division of the Interborough Rapid Transit Company now has in use upwards of 120 miles of cable of this character, operating at a potential of 10,500 volts, and during the last nine months there have been only two failures of cable insulation, one of which, however, did not cause any interruption of service.

At St. Paul, Minnesota, the gas light company has, for the past four years, successfully operated cable of this kind under a potential exceeding 20,000 volts, and recently in developing plans for an important transmission project I have received from two reliable manufacturing companies quotations upon paper-insulated cables guaranteed for service under a potential of 33,000 volts, alternating. There is no reason to doubt that cable of this type, constructed under proper specifications and with sufficient care may now be considered thoroughly reliable for commercial service under such potentials as these, provided proper precautions are observed in the arrangement of circuits and in the installation of protective devices to prevent such cables being subjected for any appreciable length of time to potentials materially exceeding the working potentials for which they are intended. The illustration on page 102 shows the construction of three-conductor cable as used by the Interborough Rapid Transit Company for 11,000-volt, three-phase distribution in ducts.

The illustrations on pages 103 and 105 show, respectively, cross sections of three-conductor, rubber-insulated, steel armoured cable and single-conductor, rubber-insulated, steel-armoured cable, as used by the same company in submarine work.

Methods of laying cables also have greatly im-

PORCELAIN INSULATORS FOR HIGH-POTENTIAL CIRCUITS



A MOTOR-OPERATED OIL SWITCH FOR 11,000-VOLT THREE-PHASE CIRCUITS, MADE BY THE GENERAL ELECTRIC COMPANY, SCHENECTADY, NEW YORK

proved. In the United States they are now usually laid in tile ducts, set in concrete. Much of this duct work is still badly done, particularly with reference to the dissipation of heat, due to currents traversing the cables; but general practice in this respect has improved greatly within the last two or three years. The illustrations on pages 104 and 106 show, respectively, a cross-section of a cable conduit and a cross-section of a manhole as used by the Manhattan division of the Interborough Rapid Transit Company.

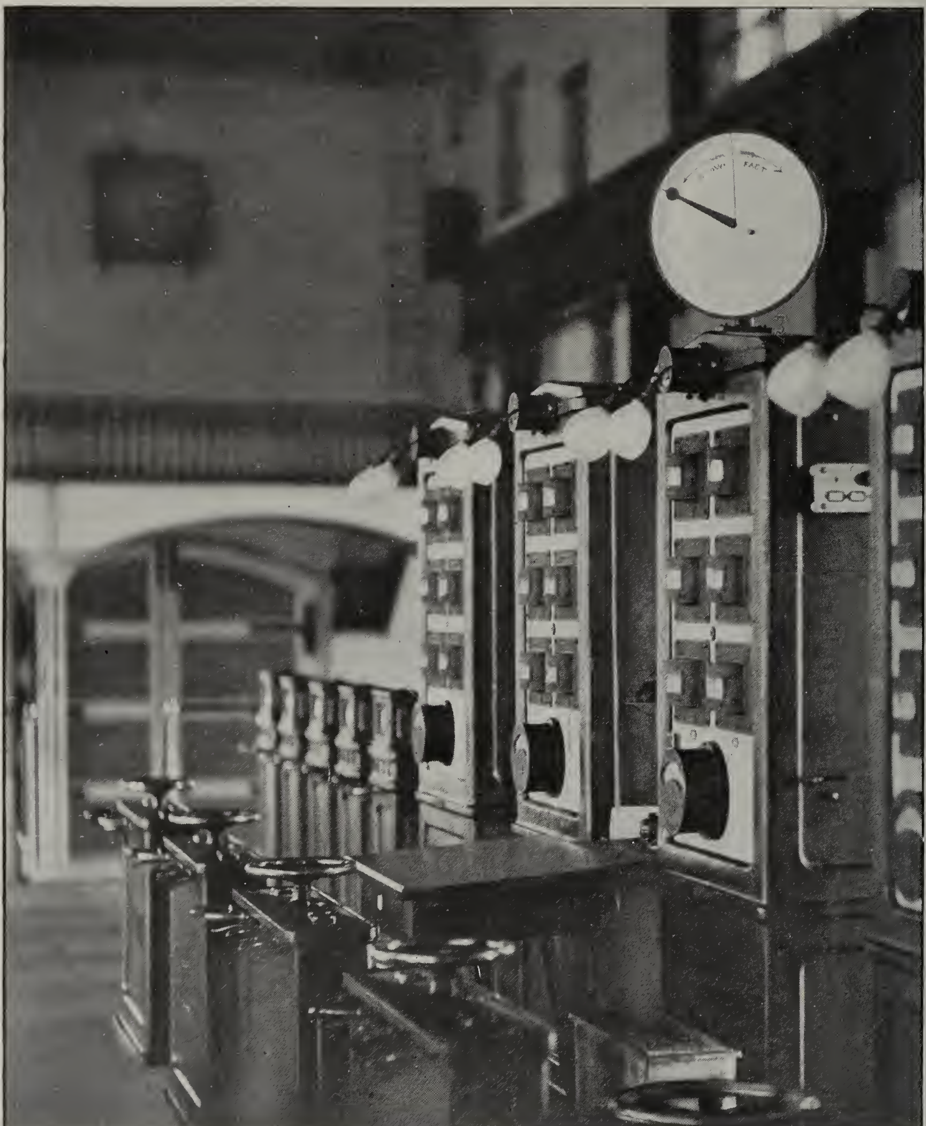
Insulators for overhead lines have been very radically improved since 1893. The insulator used in the Frankfort-Lauffen transmission employed an oil cup to decrease surface leakage. Dust and other material, accumulating upon the surface of the oil, destroy its insulating value, and this type of insulator is, therefore, not now used commercially. The 10,000-volt plant at Pomona and San Bernardino, California, installed in 1890 and still in successful operation, uses a double-petticoat glass insulator designed by Morris, of the Westinghouse Company, and the writer, and in 1895 this insulator was successfully used by Mershon during the high-potential tests which he conducted at Telluride, Colorado, under a potential of 45,000 volts.

The so-called "Type C" insulator, as used by the Niagara Falls Power Company upon the first pole line, erected between the Falls and Buffalo, and the "Type E" insulator, as used upon the second pole line, erected in 1900, are shown in section on page 108. The former was particularly defective in respect to its mechanical attachment to the pin, which was but 7/8 inch in diameter at the top, while the number of screw threads engaging pin with insulator was but six. The pin used with the "Type E" insulator is 1 1/2 inches in diameter at the top, and nine threads secure the insulator to the pin. The Niagara Falls Power Company increased the line potential between Niagara and Buffalo from 11,000 volts to 22,000 volts in the spring of 1901, and since that time has been replacing gradually the "Type C" insulators on the old line by insulators of the newer type, which have been very successful.

On page 109 are shown illustrations of three insulators. The smallest is "Type E," as now used at Niagara, while the largest is an insulator made by the Locke Insulator Manufacturing Company, of Victor, New York, for very high voltage. This insulator has been selected for the 101-mile transmission plant of the Guanajuato Power & Electric Company, in Mexico, which company is now using successfully a potential of 60,000 volts. The insulator of intermediate size is one which the writer designed several years ago for line potentials of from 40,000 to 50,000 volts. It is the largest porcelain insulator made in a single piece, the Locke insulator being made in several concentric materials or cups which are cemented together. Many other insulators effective for line potentials up to 50,000 volts are now available, and some of the more recent of these are designed for pins of adequate size.

Probably the most valuable single addition to apparatus developed since 1893 for high-potential transmission is the electrically-operated oil switch. The illustration on page 110 gives an excellent idea of its construction, as built by the General Electric Company, of Schenectady, New York, for 11,000 volt, three-phase circuits.

Two breaks are provided for each of the three sides of the circuit, and in opening the circuit the break is made under oil contained in large metal cylinders. Each cylinder contains a fixed terminal. When the switch is closed, current passes from one terminal of each pair to the other through two vertical rods of copper connected at their upper ends. The switch parts belonging to each of the three sides of the circuit are separated from all other parts of the switch and its mechanism by being enclosed in a brick compartment with vertical partitions of soapstone, as shown in the illustration. The moving parts of the switch are operated by mechanism located upon the top of the brick compartment, this mechanism being, in turn, actuated by an



LINCOLN SYNCHRONISM INDICATOR AS USED BY THE NIAGARA FALLS POWER COMPANY

electric motor which is controlled by circuits extending from the control board, or pilot board as it is sometimes called. At the control board the operator has before him a small switch, sometimes two, corresponding to each of the large three-phase switches, and the movements of the latter are controlled by opening and closing the former.

The plan of opening and closing switches located at a distance from the operator by compressed air or electricity was first adopted, I believe, by the Westinghouse Company in connection with the switch gear installed in the first power house of the Niagara Falls Power Company. In that plant the plan demonstrated its value, and it is now generally and in fact almost necessarily

adopted in the case of all large modern plants. The sense of security enjoyed by the operator while controlling these great switches at a distance results in confidence which goes far to ensure that precision which is so absolutely essential.

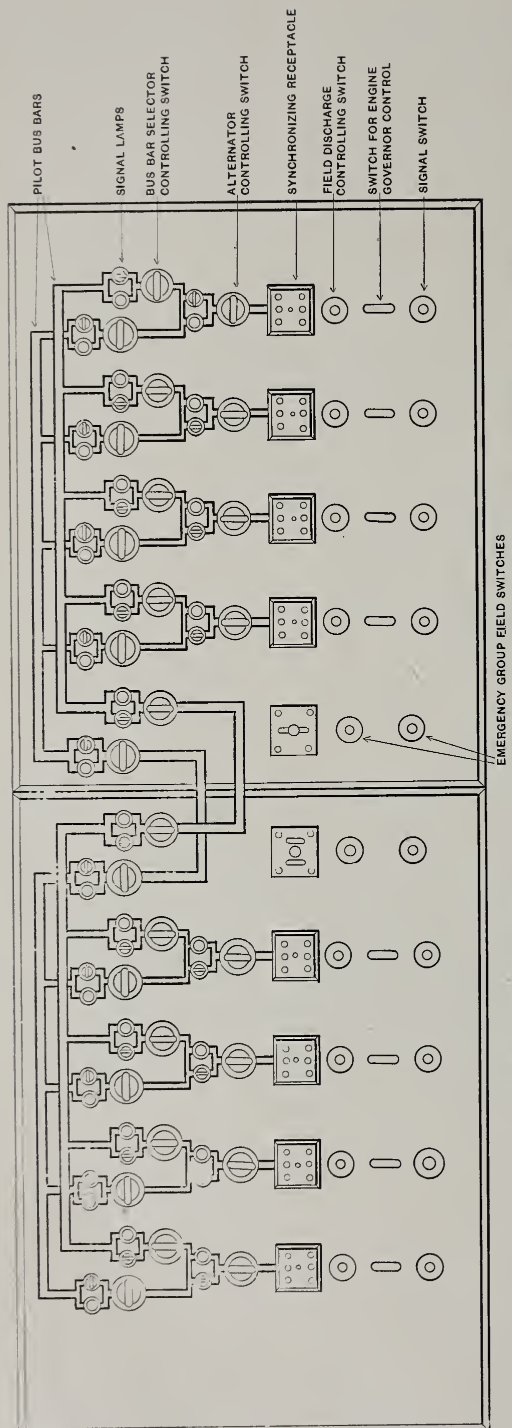
At the Manhattan Railway power plant in New York City sixty-six switches of this type are installed, and, on the average, have been in use about eighteen months. During that time not one of these switches has failed to operate as and when expected, and while some of them have been called upon to open automatically circuits in which extremely heavy short-circuited currents were flowing, they have done this without damage other than some spilling of oil from the oil cups.

The illustration on page 112 shows a synchronism indicator as installed upon Switchboard No. 1 in Power House No. 1 at Niagara Falls. This synchronism indicator, invented by Mr. Paul M. Lincoln, is an ingenious and most useful adjunct to a power plant using alternators. When an alternator is to be connected in parallel to bus bars supplied by one or more alternators the synchronism indicator is connected to the circuits through suitable transformers and becomes a perfect guide to the operator. The index arm of the indicator revolves at a speed proportional to the difference in speed between the alternator to be synchronised and the alternators supplying the bus bars, and it shows also which of the two is running at the higher speed. As used at Niagara, it is of very large size, and is mounted upon a vertical shaft which makes it possible to turn the face of the instrument so that it becomes visible not only to the operator upon the switchboard who throws the switches, but also to the governor attendant upon the floor who is adjusting the speed of the alternator preliminary to the operation of synchronising.

Still another comparatively recent auxiliary of value in the operation of large plants is the diagrammatic pilot board illustrated on pages 114 and 115. In this arrangement of the operating switches which control the power switches at a distance, dummy bus bars and other apparent (but not real) connections are provided and assembled in connection with the operating switches in such a way as to place before the operator at all times a diagram of the existing connections of the power circuits. Every time he changes the position of the pilot or control switches he alters the diagram to conform to the resulting connections of the power circuits, the diagram as indicated to the eye by handles of the pilot switches being corroborated by red and green signal lamps, one or the other of which is lighted when the corresponding power switch reaches the end of its travel in the movement incident to opening or closing the circuit. The illustrations on pages 114 and 115 show the diagrammatic pilot board and the instrument board as used for controlling the operation of eight 5000-KW alternators at the Manhattan power plant.

The development of the oil switch, which is capable not only of reliably making and breaking circuits in ordinary operation of the plant, but also of opening circuits traversed by short-circuiting currents as a result of failure of insulation, opens the way to the effective use of the time-limit relay attachment and of the reverse current relay attachment for such switches used as automatic circuit-breakers. The respective functions of these two relay attachments can be described best by reference to the diagram on page 116.

This diagram shows the essential connections of power circuits in a power plant comprising five alternators and transmitting power to a sub-station through two cables or overhead circuits. To simplify the diagram, the arrangement shown is that required for a single-phase apparatus, and but one set of bus bars is shown in the power house and also in the sub-station. From the sub-station four circuits serve to distribute power at low potential. If no time-limit circuit-breakers be used, a heavy short-circuit upon one of the distributing circuits from the sub-station may result in opening not only the circuit-breaker or fuse located in the sub-station to cut off

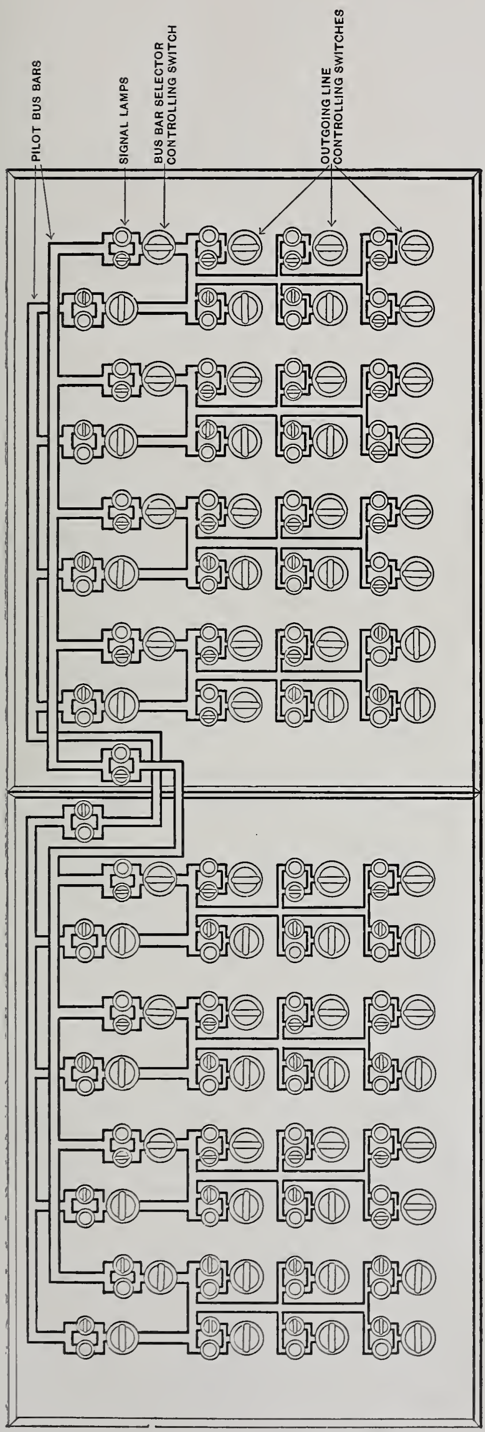


ALTERNATOR CONTROLLING BENCH BOARD USED BY THE MANHATTAN RAILWAY COMPANY, NEW YORK

the particular circuit affected, but also the circuit-breakers or other devices located at the power house and intended to cut off one or the other of the transmission circuits in case of a heavy short-circuit between power house and sub-station.

Instances have been known where even the automatic circuit-opening devices between dynamos and bus-bars have been opened as a result of a short-circuit beyond the transformers in the sub-station. If the time-limit relay be used in connection with the circuit-breakers, and if it be set, say, for three seconds in the case of circuit-breakers between dynamos and bus-bars, one second in the case of circuit-breakers in the transmission circuits at the power house end of the line and for instantaneous operation in distributing circuits from sub-station, the circuit-breaker in the distributing circuits at the sub-station may be relied upon to open before those in the transmission circuit at the power house, and, of course, also before those in the dynamo circuits at the power house can open. The interruption of service, therefore, which results from failure of insulation in one of the distributing circuits from the sub-station will be limited to the supply of power through the particular distributing circuit affected.

The reversed current circuit-breaker, which should be an equally valuable adjunct to a transmission plant, unfortunately, as has been said, is not yet available in thoroughly satisfactory form. Andrews used it between alternators and bus-bars for the purpose of cutting out an alternator which might become short-circuited. It is equally applicable, of course, to alternating-current circuits between a power house and sub-station, provided the circuits are connected in multiple with each other at both ends of the line.



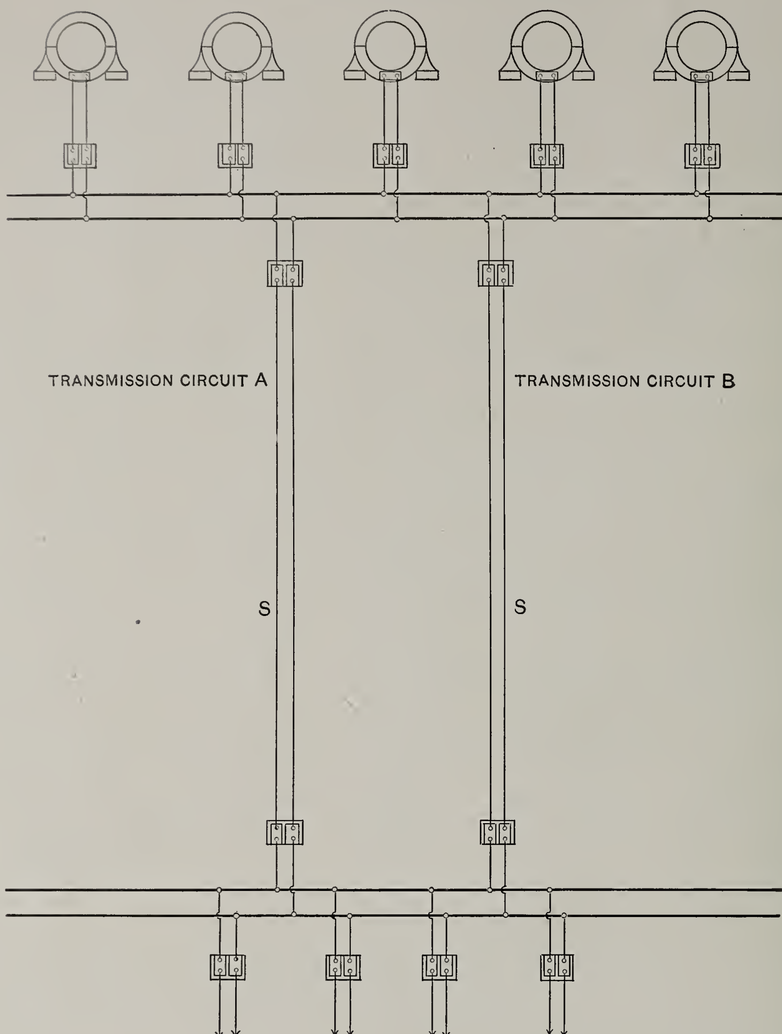
ALTERNATING CURRENT FEEDER CONTROLLING BENCH BOARD USED BY THE MANHATTAN RAILWAY COMPANY, NEW YORK

Referring again to the diagram on page 116, we may imagine that a short-circuit occurs on a transmission circuit, designated *A*, at the instant of maximum flow of current in one direction, which, for convenience, we may call positive. It is evident that the instant the insulation between conductors of circuit *A* is broken down, *e. g.*, at point designated *S*, current will flow from the bus-bars at the power house and also from bus-bars at the sub-station toward the point *S*. This implies a reversal in the direction of flow of current between the bus-bars at the sub-station and the point *S*, as compared with its direction at the given instant had no short-circuit occurred. This reversal may be utilised to open the circuit-breaker by actuating a relay device.

Practically all of the reversed current relays thus far tried in the United States have proved unsatisfactory by reason of the fact that they require a potential in phase with bus-bars at sub-stations, and in case of very heavy short-circuits this potential usually drops below the limit effective for operation. The required potential might be obtained from a small alternator, normally operated in synchronism with the power supply and equipped with a fly-wheel of sufficient size to keep the alternator going at synchronous speed for the necessary fraction of a second after the occurrence of the short-circuit, or perhaps better means might be devised for accomplishing the same purpose.

Where three or more circuits between power house and sub-station are available, reversed current relays can be operated by difference in current flowing through the short-circuited line and the other lines, and relays of this type are now upon the market.

Without entering further into discussion of details, it will be



TYPICAL DIAGRAM ILLUSTRATING USE OF TIME LIMIT AND REVERSED CURRENT CIRCUIT BREAKERS

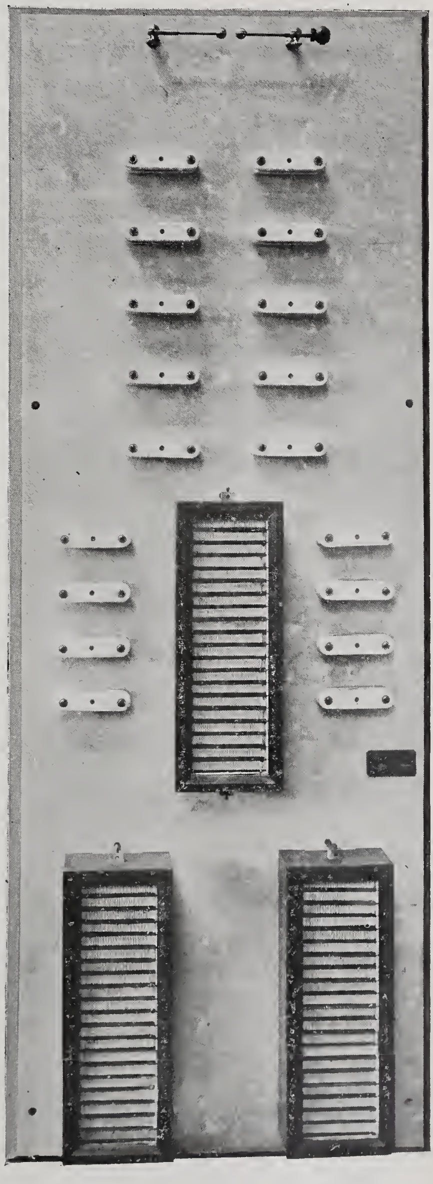
evident that proper use of the time-limit relay and of the reversed current relay, in combination with the oil switches now available, afford means for effectively localising the troubles resulting from any short-circuit in an interconnected alternating-current system of distribution which is carefully laid out with a view to such localisation.

Perhaps no adjunct of a successful transmission plant employing overhead circuits is more important than the lightning arrester, and in the development of none has more remarkable progress been made since the days immediately following the Lawrenceville test. For this progress we are indebted chiefly to Alexander J. Wurts. The first alternating-current plants in America used the brass "saw tooth" arrester which was then in general use by the telegraph companies. Bitter experience soon demonstrated the futility of this device when applied to 1100-volt, constant-potential circuits, supplied by dynamos having low internal resistance, and it was soon displaced by a flood of ingenious and more or less effective

arresters, which, in turn, were effectively superseded by the so-called non-arcing metal arrester discovered by Wurts in 1892. The problem was to provide an easy path from conductor to earth for static electricity due to lightning and to prevent the dynamic current following in the path of the static discharge and short-circuiting the system. This, for potentials up to about 25,000 volts, has been effectively accomplished by means of the non-arcing metal cylinders. For higher potentials, the performance of lightning arresters is not yet altogether reliable. The illustration on this page shows a modern lightning arrester outfit for a 25,000-volt circuit. Detail descriptions have been printed in various technical journals and in advertising publications of manufacturing companies.

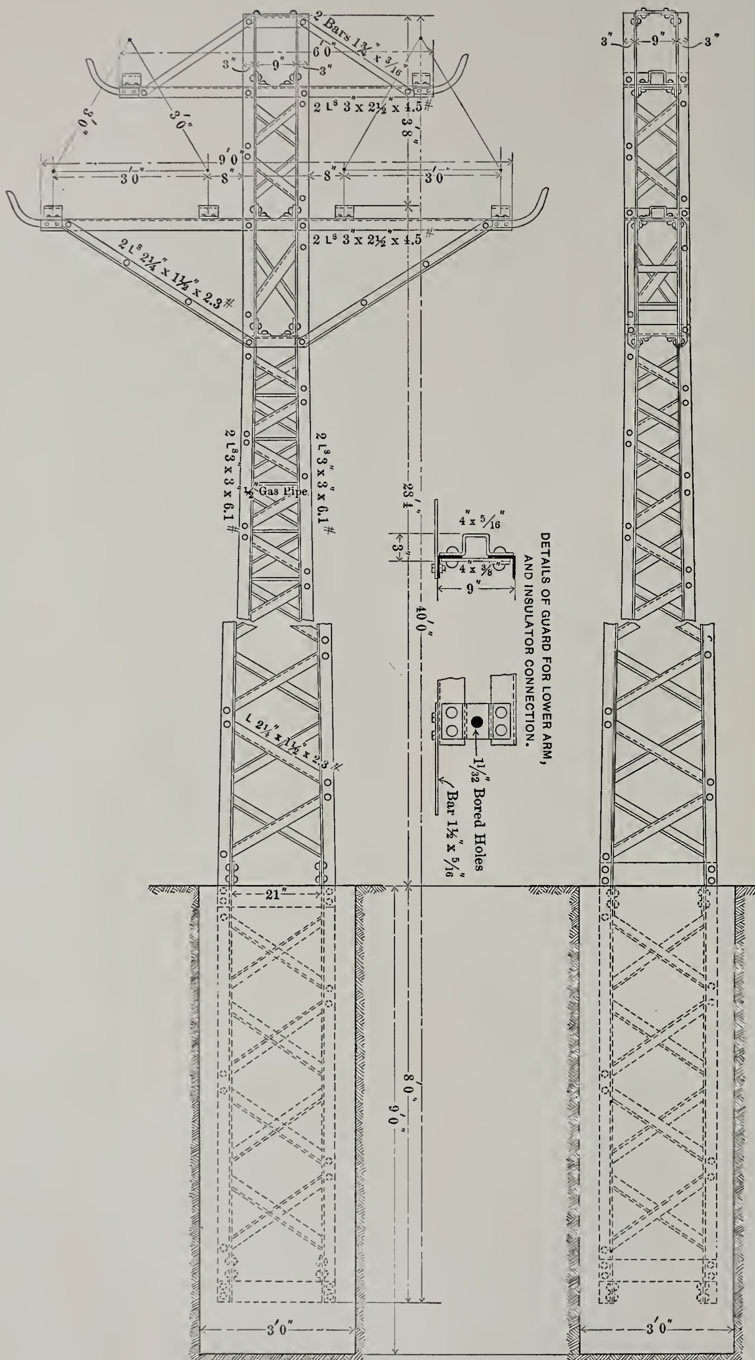
As regards line construction, it is to be regretted that few plants in the United States up to the present time have erected transmission circuits which, from the standpoint of permanence, compare favourably with approved European practice as illustrated, for example, in the illustration on page 120, showing the steel pole line used between Paderno and Milan. For this illustration I am indebted to Mr. Guido Semenza, the very able engineer of this important and interesting plant. Nearly all pole lines in America are of wood, and, so far as insulation is concerned, there is much to be said in favour of this material. In my opinion, however, the lines of the future will use steel poles or towers, widely spaced, and will rely for insulation exclusively upon the insulators to which the conductors are attached. The idea of using steel poles is not new in America.*

The illustration on page 118 shows a design for a steel pole carrying two transmission circuits, as designed under the writer's direction in 1894 by the Pittsburgh Bridge Company and submitted to the Cataract Construction Company with reference to the then proposed transmission from Niagara to Buffalo. It will be noted that the three conductors of each circuit are triangled,



A LIGHTNING ARRESTER FOR 25,000-VOLT ALTERNATING CURRENT CIRCUITS

* Since this article was written, the writer has been furnished, through the courtesy of Mr. Henry Hine, president of the Guanajuato Power & Electric Co., Mexico, with a description of the steel tower construction adopted by that company, which marks a most interesting and important advance in the art of electric power transmission in America, not only by reason of the substitution of steel towers for the usual wooden poles, but also because of the long spans used. Further reference to this remarkable example of modern line construction will be made in a future article.

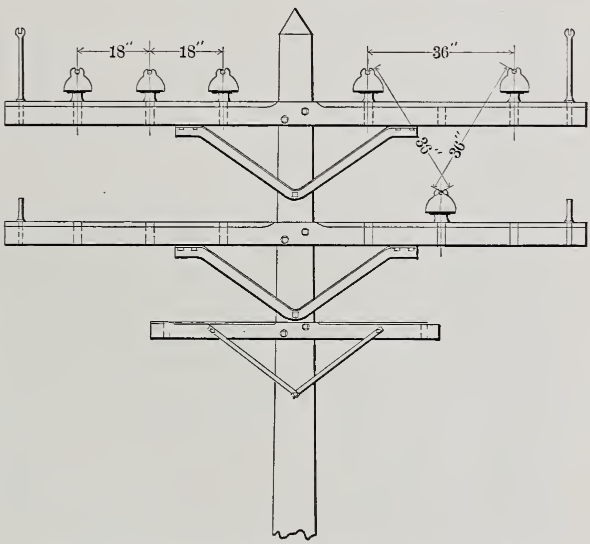


A 40 FOOT STEEL POLE DESIGNED BY THE PITTSBURGH BRIDGE COMPANY

the sides of the equilateral triangle measuring 36 inches.

Unfortunately, this plan was rejected, and the first pole line carrying two circuits was erected between Niagara Falls and Buffalo in line with the plan illustrated on this page, both circuits originally being carried upon the upper cross-arm, the three wires constituting each circuit being spaced at intervals of 18 inches and carried at the same level as shown at the left.

This arrangement was a great temptation to mischievous boys, who threw wires and sticks across the line wire. Owing to the position of the conductors they inevitably came in contact with at least two sides of the circuit, causing tremendous short-circuits, which blazed along the line until the power was cut off. The light of these short-circuits in some cases was seen at a distance of a mile, and unless the power was cut off at the power house they inevitably resulted in burning off and dropping the conductors of the transmission circuit. The triangular arrangement of conductors illustrated on the right hand side of the drawing on this page shows the location of the conductors of the first two circuits as subsequently located. In this position they have given little trouble.

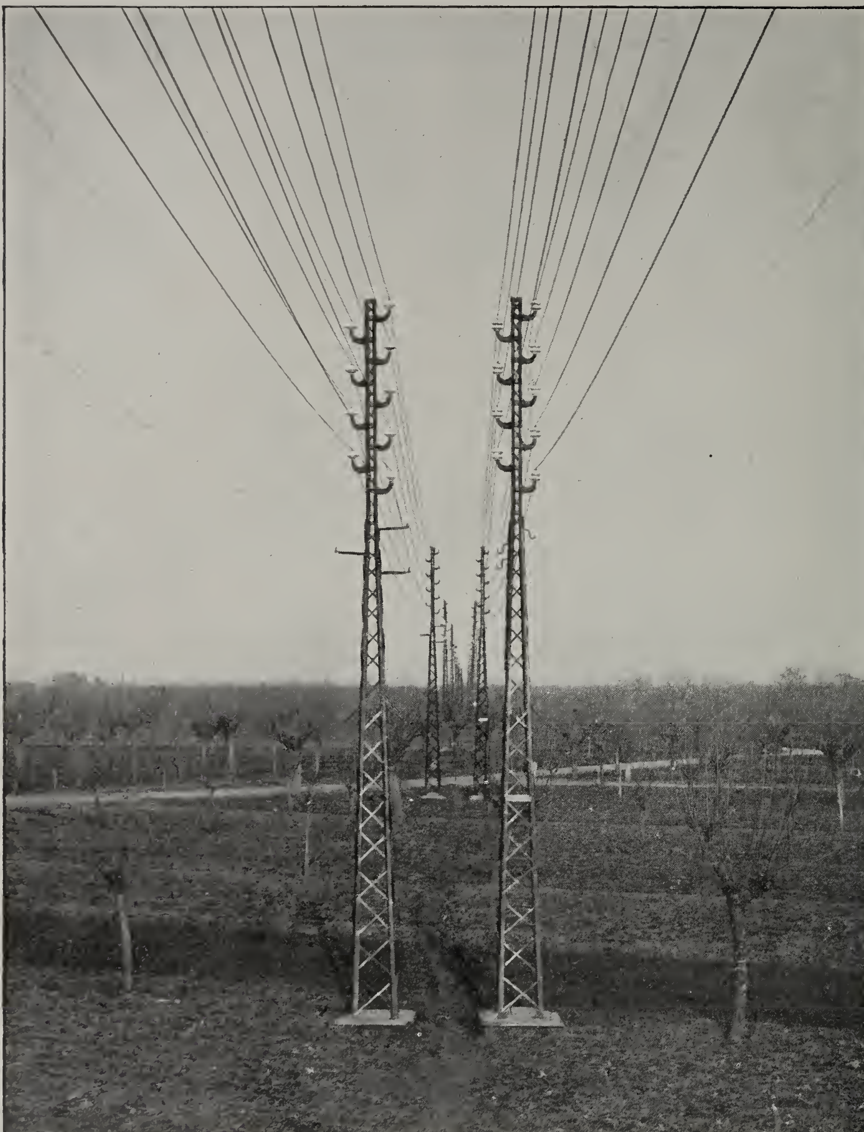


POSITION OF INSULATORS ON THE FIRST NIAGARA-BUFFALO POLE LINE

Enough has been said to show that engineers who to-day are designing electric power plants have available for use much highly important, if not absolutely essential, apparatus which did not exist ten years ago. Efficiency of dynamo, transformer, and motor has improved since then, but it has gained little as compared with the development of such auxiliary apparatus as has been referred to here. The latest dynamo installed at Niagara is not materially more efficient than the first one which was put into commercial operation there in 1895; but line insulators, cable insulation, switches, and relay devices for automatic circuit-breakers are incomparably superior to any that existed at that time.

Doubtless further improvement in respect to details of construction is to be expected, but the apparatus available to-day is such that transmission at 60,000 volts should be more reliable than transmission at 6000 volts was ten years ago. Accurate and extensive knowledge and sound judgment the engineer who designs and installs such a plant must have, but the materials are now available if he knows where to find and how to use them.

Considering the probabilities of future development of electric transmission, it is reasonable to expect that the utilisation of water-powers will continue until practically all of any considerable magnitude are put to work. The ability to employ higher potentials means ability to span greater distances, and thus markets will be found for water-powers which hitherto have been deemed too remote from industrial markets for profitable utilisation. Improved reliability and gradually lessening cost of apparatus will co-operate influentially toward this result, as will also the decrease in rates



STEEL POLE LINE AND CIRCUITS ON THE MILAN-PADERNO TRANSMISSION, ITALY

of interest upon capital which has been so marked in recent years.

It is to be expected also that power plants using steam or gas engines to drive dynamos and distribute power electrically over large districts will be constructed. Recently in Great Britain a number of corporations have been chartered with this object in view. Some of these plants are now under construction, and the commercial results of their operation will be of great interest. So far as I am aware, nothing of this kind on a large scale has been attempted up to the present time in America; but there are undoubtedly districts where such enterprises should be profitable.

The opportunity for profit rests chiefly upon three facts:—(1) that power can

be produced more economically by a very large steam plant than by a small one; (2) that the aggregate power which a central station plant, supplying a certain district, is called upon to develop at any given time is very much less than the sum of the maximum outputs of the small plants required to do the same work; and (3) that an electric motor occupies much less space and requires less attention than a steam plant. A 50,000 horse-power steam plant, supplying electric power for general purposes to a district having a radius of fifty miles, will burn about 3 lbs. of coal per average kilowatt-hour delivered throughout the district, while the average consumption of coal by the steam plants which such a central power plant would displace is usually not less than 10 lbs. per kilowatt-hour.

As regards ratio of the maximum output of the central station to the sum of the maximum outputs of the displaced small plants, definite generalisation is impossible, because everything will depend upon the kind of work done by the small plants. I think it safe, however, to say that this ratio will rarely, if ever, be higher than 2 to 3, and in some instances which have come under my observation it is as low as 1 to 3. In other words, a 50,000 horse-power central station plant will rarely, if ever, fail to do the work of small plants aggregating 75,000 horse-power, and in some instances will be capable of doing the work of small plants aggregating 150,000 horse-power.

Transmission of power from coal fields to large cities works out much less favourably, since in this case it must compete with the alternative plan of transporting the coal to the city or to a point near it and there generating electric power in a steam plant equally economical and equally deriving the benefit which results from the fact that a single large plant can displace a large number of small plants whose aggregate output considerably exceeds its own. In this case, the plant located at a distance from the city must be larger by an amount equivalent to the maximum losses in transmission, and the fuel burned for a given delivery of power in the city will exceed the amount which would be burned if the plant were located in or near the city by an amount proportioned to the average square of the power transmitted.

Generally speaking, the difference in the cost of coal delivered to a plant in the city and the cost of coal delivered to a similar plant located in the coal fields at a distance of 250 miles from the city will not represent as much as 10 per cent. upon the difference in annual cost of the two plants thus respectively located, and when we take into account the possibilities of interruption of service in the case of the plant located at a distance, it appears evident that in the present state of the art of transmission, the better plan is to locate the central station near the city and pay the cost of transporting the coal to the point.

But what may prove to be the greatest of all fields for alternating-current transmission now confronts us in the application of electricity to the operation of railways. The successful substitution of electricity for steam by Ganz & Co., of Buda-Pesth, upon the Valtelina line, in Italy, by which a great economy has been effected in cost of operation of a railway more than sixty miles long, is an object lesson of great significance. Freight as well as passenger traffic is handled successfully under very severe conditions of grade, curvature, and climate, and the economy resulting from the substitution of electricity for steam challenges the attention of railway managers and engineers.

The recent high-speed trials at Zossen, Germany, in which a fifteen-ton car, operated electrically, attained a speed exceeding 131 miles an hour, invite attention in the same direction, and the development of two single-phase, alternating-current motors in America and of two similar motors in Europe, each of which is stated to meet effectively the requirements of railway service, mark by far the most interesting and important practical step of this new century in the use of electricity for power purposes.

LONG-DISTANCE POWER TRANSMISSION

ITS ECONOMIC AND ENGINEERING ASPECTS

By Charles F. Scott

LONG-DISTANCE transmission of power may be considered from any one of several points of view. Considering it from its economic aspect, one who has not given particular thought to the subject will be astonished to find, on analysis, to how great an extent the operations of modern life depend upon the use of mechanical power. Its importance is most forcibly realised when the supply of power is cut off by a coal famine. Railways, steamships, tramcars, mills, factories, electric lights, all are brought to a standstill, and the production of ice in summer as well as heat in winter is interrupted. Any agent which enables power to be transmitted over long distances, so that water-power, which would otherwise be of little or no consequence, is rendered of immediate and practical value, brings into commission a new source of power. This may be of little moment where fuel is abundant, but it is of vital importance where fuel is scarce and water-power is available within a practicable radius.

Electric transmission not only makes available a new source of power, but it insures in its distribution those advantages, notably flexibility and ease of application, which are incident to the electric motor. Electric transmission and distribution, therefore, take a very important place in the general economic problem of supplying cheap and abundant power, upon which modern industry and commerce and social life have come to depend so vitally.

Power transmission may be viewed also from the financial standpoint. The transmission plant may be considered as an investment of which the value is dependent entirely upon the financial returns. From such a standpoint it is immaterial what becomes of the power; it may be devoted to a useful purpose or it may be wasted,—the one point at issue is the question whether the investment will pay a satisfactory return. The problem, in the main, is not unlike that pertaining to other lines of business. There is a certain first cost, and there are operating expenses and the like which are to be balanced against the income.

The fundamental characteristics which pertain to other enterprises apply to power transmission also. A power transmission plant, simply because it employs electricity, has no magic or potent influence whereby it may overcome the disappointments which are liable to follow rash financial speculations, stock jobbing or various kinds of mismanagement or short-sighted policy which would bring disaster to other enterprises. The increasing amount of capital which is being devoted to the development of new powers, as well as the extension of those which are well established, are substantial indications of the healthy financial basis upon which, in general, these enterprises are founded.

Power transmission may be considered from the scientific or electrical point of view. Those who are interested in this phase of the subject delight in those technical dissertations which deal with resonance and capacity and the phenomena which appear or which take on a new order of importance as voltages are increased. From this

standpoint also one might consider the technical details in the design of high-tension apparatus in an investigation requiring a knowledge of electrical theory, an intimate acquaintance with the properties of insulating materials, supplemented by observation and experience.

There is another view of power transmission which may be considered, namely, the engineering aspect. The point of view is not that of the theoretical electrician or scientist, but rather that of the man who stands apart and views the subject from without. To this aspect of the subject it is proposed to give particular attention. What, in the engineering sense, has been the trend in the development of long-distance transmission? What in general have been the problems which have been encountered, and how have the difficulties been overcome? What is the present state of the art, and what is likely to be the course of its immediate extension or development? The subjects which are brought to the front in these questions are those which are to be discussed in the following paragraphs.

In looking back, I recall an early book on the electric transmission of power, printed fifteen or sixteen years ago. Although there are many branches of learning, and even of science and of engineering, in which a book which is fifteen years old may be a credible work of reference,—indeed, the last edition of the Encyclopædia Britannica, which still has a wide circulation, is even older,—nevertheless this book on power transmission cannot be received as an acceptable standard for the present state of the art.

It opens with a description, simple and elementary, of the principles and construction of the electric machine,—the dynamo and the motor,—and there is a discussion of the relation between current and voltage and power and of the loss in conductors. There is a lengthy dissertation upon the characteristics and relative value of various methods of power transmission, hydraulic, pneumatic, by wire ropes and other mechanical means, and by electricity. The part pertaining to long-distance transmission is devoted to a discussion of the series-wound, direct-current motor for use in a system employing a constant current and in which the high voltage is obtained by connecting several generators and also several motors in series. The book, excellent in itself, is not suitable as a work for practical guidance in transmission to-day for two reasons,—first, the system it describes receives at present no serious consideration, no such system has ever been installed in America, and there have been but few elsewhere; second, the system in use to-day is not considered in the book,—it is a later development.

Nor is the present system either a simple evolution from the one described, or even a modification of it,—the present system differs *in toto*. One is direct current, the other is alternating; one is constant current with machines in series, the other is constant potential with machines in parallel. Speaking generally, the entire development of a long-distance power transmission as employed to-day in the transmission of millions of horse-power has been from beginnings which did not receive consideration in an engineering treatise on the subject published fifteen years ago. It has, indeed, been but ten years since the savants, who were to advise the electrical system to be adopted at Niagara Falls, finally and officially decided that alternating and not direct current should be used.

What are the fundamental elements which have given the alternating-current system precedence, and what have been the stages in its so rapid development to its present state of commercial usefulness? The one fundamental thing which underlies the adoption of the alternating current and the development of modern electrical transmission is the transformer. Its principle, its functions, and its purpose are so well known that they require no elementary exposition. It may be of interest, however, to point out a very simple mechanical analogue in the transmission of mechanical power by a belt. If a power is to be transmitted from an engine shaft 8 or 10

inches in diameter to a second shaft parallel with it, a belt which could be placed directly on the two shafts would serve to transmit energy if they were of proper relative diameters, and would also effect any change in speed which might be desired. If the power to be transmitted were small, a horse-power or so, nothing further would be needed; but if it were several hundred horse-power, the size of belt for transmitting would be so large as to make it impracticable.

In order that a large power may be transmitted by a small belt it is necessary to increase the diameter of the pulleys and the speed of the belt. If the pulleys were of sufficiently large diameter, the pull upon the belt would be so small that a mere thread could transmit a hundred horse-power. Such an arrangement is mechanically impracticable, although the electrical analogue does not suffer the same limitations. When mechanical power is transmitted, the higher the belt speed, the less the size of the belt required for transmitting a given horse-power; likewise in an electric circuit, the higher the voltage of the transmission, the less need be the size of conductor necessary. By means of pulleys of suitable diameter the desired relation between speed and belt tension is secured in one case, and by means of transformers with suitable windings the desired relation between current and pressure is obtained for the electric transmission. Through the intervention of the transformer transmission pressures are usually not controlled or limited either by the voltage of the generator or the voltage of the distribution current. A generator may supply current directly to the circuits for lighting, or it may be removed many miles, and the current actually transmitted may be only one-hundredth part of that either in the generator or in the lamps.

This well-known characteristic of the transformer has been fundamental in the great development, not only of the alternating-current system, but of long-distance electrical transmission as well, as the transmissions of to-day have been made possible and practical by the alternating current.

The transformer is beautifully simple in its elementary principles and in its construction,—without moving parts, of high efficiency and automatic regulation, admirably adapted for its place in a transmission system. There is, however, a vast difference between the simple elementary form of transformer, in which two separate coils are linked together with an iron core, and the modern power transformer designed to transform hundreds or thousands of kilowatts at high voltages. Problems in the arrangement of the windings into a considerable number of coils, the problem of removing the heat generated throughout a large mass of material without undue elevation of temperature, problems of mechanically supporting heavy windings which are subjected to mechanical forces tending to produce vibration or distortion of the coils, as well as the problem of insulating the transformer to withstand the very high voltages which are normal to the service and those which may accidentally appear, due to lightning or other causes,—all these things have brought into transformer design and construction many elements of both theoretical and practical difficulty.

The evolution of the transformer in the few years which have passed from the time when 40 or 50 KW at 5000 or 10,000 volts were the limit to the present time when transformers are built for two or three thousand kilowatts and 50,000 or 60,000 volts, has required the highest skill in design and in construction to overcome the new difficulties which have continually arisen as sizes and voltages have increased. The transformer, however, has held its own, and its output has been made as large as other units in transmission systems have required, and it has supplied voltages as high as have been demanded by the transmission circuits.

The critical and limiting element in a long-distance transmission system is the transmission circuit. High voltages introduce exacting requirements upon the insulators. The insulator is subjected

to mechanical strains, and must, therefore, possess adequate mechanical strength. Its material must be such as will resist puncture from the constant electrical stresses which are brought upon it, and its form and dimensions must be such as to prevent the passage of a trivial current over its surface which would quickly result in the formation of an arc.

The art of insulator making has undergone a wonderful evolution in the past six or eight years. The first insulators which were placed upon one of the most noted transmission circuits were of large size, designed and made especially for the high voltage which was to be carried. They were found to be inadequate, and as soon as others were available they were removed from the power line and tested. It was then found that the porcelain was not homogeneous, that there were openings and cracks and spongy places. When soaked in water not more than two or three insulators from the whole line of many miles in length would withstand the normal line voltage, which was only 11,000 volts. Great difficulty was experienced several years ago in getting glass insulators, which were very much smaller and lighter than those which are now regular commercial products.

The essential requisites in an ideally simple transmission circuit are the raising and lowering transformers and the line, and in the latter the insulator is the critical element. There are auxiliaries, however, which are scarcely less important to the successful operation of a transmission circuit. Notable among these is the protection from lightning or static disturbances from which sudden and very high pressures may occur which may easily break down insulation ample for the ordinary operating pressure of the system. The behaviour of these instantaneous pressures is seemingly very erratic and completely disregards the ordinary laws of alternating current. Indeed, these pressures are as mysterious as are the phenomena of ordinary alternating current to one who has been familiar only with direct current.

The phenomena resulting from lightning are comparable to those resulting from sudden impact in mechanics. A mechanical device which may be fully adequate for its ordinary service may be broken and shattered by a blow. Mathematical research can, in a way, aid in an understanding of the general problem, and while experimental and laboratory investigation may do much to determine the relative strength and resistance of the different parts of a transformer or other apparatus to resist the stresses which come from high voltages, these alone are insufficient. In addition, there must be tests and careful observation under the conditions in actual service. It is the function of the protective apparatus to relieve the transformer from the abnormal strains to which it would otherwise be subjected.

It is usual to provide a short path, such as a spark gap, by which the charge at high voltage may pass without disturbance to the apparatus. The passage of a momentary current across such a gap breaks down the air insulation and thereby produces a short circuit, so that the ordinary voltage of the line which was insufficient to break down the air gap in its initial condition will cause the flow of a very excessive current. Means of one kind or another must be devised to prevent or instantly interrupt such a flow of current, otherwise there will be an interruption to the service. On the other hand, the introduction of means for interrupting the current must not be of such a character as to impede the freedom of discharge, which is the fundamental object of the lightning arrester.

The development of a lightning arrester for the ordinary low voltages is a problem which has called forth the best energies of many able electricians. Even 500-volt railway apparatus is, unfortunately, not wholly immune to lightning. Each increase in voltage brings its new problems. The arrester for 5000 or 10,000 volts presents a quite different problem from that encountered at 1000 or 2000 volts, while the arrester for 40,000 or 50,000 volts again brings in difficulties of a new order.

The design of switches for operation

at high voltages, the arrangement of high-voltage bus-bars, circuits and wiring in stations, and the bringing of wires through the station walls are matters of very great importance, an importance, moreover, which is often not appreciated, and types of construction have been employed which, while quite satisfactory for low voltages, are wholly inadequate for higher voltages.

The several elements in the transmission system which have been discussed at greater or less length, including the transformer, the insulator, the protective apparatus and general station arrangements, have to do with the constructive, rather than the operative, features of a plant. A transmission system is a link between the power-house and the substation. In the power house the whole object is the proper generation of current for the transmission line. The design and arrangement of prime mover, either water-wheel or engine, together with its speed-governing features, also the generators, switchboard, indicating instruments, and the like, all form one unit which must operate uniformly and steadily to supply current to the circuit.

At the sub-station there may be switchboards, motor-generators, rotary converters, and distributing circuits for motors and lights. These require, in general, a steady and constant supply of current at a constant voltage. The rotary converters and such synchronous motors as may be used must act in exact synchronism with the generators. Irregularity or fluctuation in speed of generators is instantly communicated to the synchronous machines in the sub-stations. If the variations are small, they may be inappreciable; if they are large, they may cause serious disturbances.

Again, the voltage at the sub-station, which should be steady and constant, is subject to various disturbing elements. Each increment of load tends to lower the speed of the prime mover, to lower the voltage of the generator, and to cause an increased loss of voltage in the transmission circuit. A considerable drop in voltage, although momentary in character, may be sufficient to cause a synchronous machine to drop out of step. This, in turn, will cause it to take an excessive current and to come to rest. A change in the field current of a synchronous machine affects not only that machine, but, to a greater or less degree, modifies the voltage of the whole system. The system becomes much more complex and the possible interactions are greatly increased when several sub-stations, and, as in some cases, several generating stations also, are all connected to one transmission system, with its radiating, branching and usually duplicate circuits, each of three conductors for three-phase current.

This hasty review of the elements in a transmission system and of the nature of its operation indicates something of the advance which has been made in the development from the simple, ideal system, including simply raising and lowering transformers, connected by a transmission line, to the modern comprehensive transmission system. In illustration of the success with which such a system can operate, the writer may state an instance of one of the early suburban railways which was operated by rotary converters. The system comprised an alternating-current generating plant with high-voltage lines connecting four or five sub-stations containing rotary converters for supplying direct current to the trolley line. In addition to these sub-stations rotary converters were placed in the power-house for receiving current directly from the low-voltage alternators and supplying direct current to the trolley line. In designing this plant a serious question was raised as to whether the voltage for the trolley line could be held within the limits of good service when the rotary converters were placed at different distances from the generator and supplied from a common transmission circuit. It was also recognised that there were many more links between engine and railway-car motor in such a system than are found when a direct-current generator supplies current directly to the trolley circuits.

Recently the writer had a conversation with the manager of this plant, who, through recent consolidations, has a number of direct-current power stations

under his supervision. He stated that the reliability of service through the alternating-current rotary converter system was greater than that in which the current is supplied from direct-current generators.

The success which has attended the alternating-current system is attested by the very large number of plants which have been supplied and the large quantities of power which are transmitted, as well as the industrial and commercial activities which are dependent upon this power supply.

The rapidity in the development of power transmission and the recognition of the serious and far-reaching problems which it involves have led the American Institute of Electrical Engineers to appoint a special committee for the collection of data and the discussion of topics relating to power transmission in general. This committee has undertaken two lines of work:—first, the collection of data, relating to construction and to operation, from managers and engineers of power plants; and second, the discussion of important subjects in transmission work. Its methods are to make a substantial aggregate out of small contributions from many active men. A leading transmission engineer has remarked that those who are not free to contribute from experience in order that by mutual interchange all may be assisted, may be suspected of being narrow-minded or having had unfortunate experiences which they fear to make known. The various members of the Transmission Committee of the Institute prepared short introductions to discussions on a number of important questions relating to transmission. These were issued some time before the annual convention of the Institute last year. A day was given to power transmission. The various topics were presented, there was written discussion from members who were not present, and there was a general discussion by those present. Either by written communication or in person nearly all of the important transmission systems of the United States and Canada were represented. The remarks were brief and to the point, so that the record is a most valuable one. Considering the work which has been done by the power transmission committee, several features impress themselves. The first of these is the broad scope of power transmission. It involves many kinds of engineering and of engineers. A pole line, for example, has mechanical elements, such as strength of poles, insulators and wires, the relations between sag and temperature, the proper crossing of lines, the necessary distance between wires, as well as various electrical elements, including resistance, induction, capacity, and the like. This is but a simple illustration of the requirements upon the engineer who undertakes the construction of a transmission plant. On the other hand, the various conditions of operation, such as have been pointed out in the foregoing parts of this paper, all show the various ramifications of the system and the variety of elements, mechanical and engineering, as well as commercial and industrial, which are brought together in one system through the transmission line.

A second generalisation from the work of the transmission committee is the importance of emergency conditions. It is the unusual, the abnormal, the accidental, which must be taken into account. Take, for example, the grouping of transformers. For three-phase transformation they may be either in the so-called delta connection or star connection. Considered from the academic standpoint, one would think particularly of the relative efficiency and regulation of transformers in the two arrangements. Considered from the standpoint of the designer, the relative sizes of wire in the transformers and the internal voltages would be the important matters. Considered from the standpoint of ordinary operation, a very important element lies in the fact that if one of the three transformers in the group be disabled and out of service, the other two may carry a partial load if the transformers be delta-connected, whereas the whole three are inoperative if they be star-connected.

In connection with one of the papers

presented at last year's annual meeting of the American Institute of Electrical Engineers, it was pointed out that there are certain possible combinations of transformers and lines which may occur through accident or improper switching of circuits in which the transformers and lines may be connected in a certain way, so that the resulting voltage may be very considerably above the normal and may become a probable source of serious burn-out, and, further, that these conditions are not only possible, but are liable to occur with transformers connected in a certain way.

In general, each element in a transmission system must be arranged to meet not only the ordinary operating conditions, but those accidental or emergency conditions which may be caused through an improper connection or accident to some other parts of the system.

A third conclusion from the discussion on power transmission is that each element in the system is the result of an evolution. Each element, be it transformer, lightning-arrester, insulator, switch, fuse circuit-breaker, or even the design of the station itself, has been subject to a regularly progressive evolution during the past ten years. Each increase in voltage has increased the difficulties of the class which had been encountered before, and has brought forward a new class of phenomena. The inventor, the designer, the manufacturer, the operator, all have steadily progressed to meet the advancing requirements. Take, for example, a collection of insulators representing the various types since the earliest transmission plants were installed, and one can see at a glance the evolution which has taken place in materials, in ideas, and in manufacture. And this process is still going on. One of the most notable instances is in the switchboard arrangements in the large power-houses recently built for alternating-current generation in the largest cities. When one remembers that it is only a dozen years or so since the introduction of marble mounted on iron framework superseded the early wooden structures, he can form some conception of the evolution which has led to a construction involving numerous galleries for bus-bars in fireproof compartments, and for high-voltage switches for generators and outgoing feeders which are operated from a central operating stand near which are placed the various indicating instruments. Every new large station exhibits improvements in apparatus or in arrangement based on the experience in the preceding stations.

To the outsider, therefore, who views the development of long-distance power transmission from the engineering standpoint there is presented a marvelous achievement which has marked one of the most notable advances in engineering.

Simple in its elements, its problems become profound and intricate as distances become longer, as voltages become higher, as the quantity of power to be handled is greater, and as the system becomes generally more extensive. Long-distance power transmission is notable for the development it has undergone,—a development produced by the combined activity of many men. There are still at work the same forces which have been at work in the past, forces which achieve results not by magic, not by wild invention or erratic ideas, but through definite, painstaking effort, in which theory and practice combine and interact to produce a regular, orderly evolution.

LIMITATIONS OF LONG-DISTANCE ELECTRIC POWER TRANSMISSION

By Paul M. Lincoln

HOW far can power be transmitted electrically?

What is the cost of transmitting electric power?

What per cent. loss takes place in transmission?

These will be recognised by any electrical engineer as typical of the questions that are continually being asked by the investor in electrical enterprises, by the users of electric power, and by the interested laymen in general. The writer has been called upon so often to answer these questions verbally that a written analysis of the elements which enter into the answers of these questions has occurred to him as likely to be acceptable. No direct answer can be given, as the answers depend upon many and varied elements, a change in any one of which may change the entire complexion of the problem. It is the intention in the following pages to present briefly the principal elements that enter to limit the distance and profitableness of electric transmission. The conditions forming the limits may be roughly divided into two classes:—

I.—The limits as placed by commercial considerations,—that is, the limits beyond which electrically transmitted power ceases to return a profit.

II.—The limits as placed by engineering considerations.

I.—COMMERCIAL LIMITS

The crucial question in any commercial enterprise,—and an electrical transmission scheme is always a commercial enterprise,—is, will it pay? There is no real limit beyond which it is impossible to deliver electric power, *provided* no limit be put upon the amount of money to be spent. The engineer could easily be found who would undertake to deliver Niagara power in Shout Africa. The difficulty would be to find the financier to put up the necessary cash. The law of supply and demand operates no less in the realm of power transmission than in any other department of commercial enterprise.

If the price that could be demanded for power in South Africa were sufficient —say a million times its present cost— the idea of delivering Niagara power to that region would not seem the absurdity that it is under present conditions. In fact, there are in operation to-day dozens of transmission lines exceeding 3000 miles in length that have been for years transmitting power successfully, both from an engineering and from a financial standpoint.

The success of these enterprises is simply a question of the price which can be successfully demanded for the power delivered. In the case to which reference is made, this price is perhaps one billion times that for which Niagara power is sold in Buffalo, or say $25,000,000,000 per K.W. per year. The writer refers to the transmission of energy in the Atlantic cables. The motion of the syphon recorder at the end of the cable is just as truly the result of power transmission as the running of a printing press or the driving of a factory. The same laws of transmission apply, whether the power transmitted be used for operating the syphon recorder or the factory. It is in the value of power transmitted that the great difference lies. If the power for driving factories were worth as much as that for operating a syphon recorder, Niagara power would, perhaps, have been sold in the markets of Europe long before this.

The distance, therefore, to which power can be successfully transmitted

by electricity depends almost entirely upon the price which can be successfully demanded for such power. The price is regulated by the law of supply and demand. The power user will buy power where he can get it cheapest and will install his own steam plant, unless the power transmission company can sell him power as cheaply as he can generate it. The most important single item in the cost of steam power is the cost of fuel. An electric transmission scheme which might fail utterly among the coal fields of a country, with coal at say $1 a ton, might succeed brilliantly in places where coal costs $10, or in South Africa, for example, with coal at say $50 a ton.

The cost of electrical power delivered at any point, which must be compared to the cost of power at the same point as obtained from other sources, may be divided into three quite distinct elements:—

1.—The cost, at the generating station, of the power delivered to the customer at the other end of the line.

2.—The cost, at the generating station, of the power lost in transmission.

3.—Interest, depreciation and maintenance of the transmission plant.

It is so evident as only to need mention, that, other things being equal, the longer the transmission, the greater the cost of the power delivered at the end of that transmission. The question that invariably confronts the electrical engineer is to deliver a given amount of power, under certain given conditions, at the minimum cost.

It may be noted that the last two items as given above vary inversely with each other,—that is, for a given proposition, if we increase the amount of copper, which is the principle upon which the third item is computed, we evidently will decrease the amount of power lost, which is the second item of cost. Lord Kelvin, in 1881, showed that the total cost for transmitting power would be a minimum, in other words, economy would be a maximum, when these two variable elements became equal to each other,— that is, when the annual cost of power lost in transmission became equal to the annual interest, depreciation and maintenance charge on the transmission plant.

Later, other writers on the same subject drew attention to the fact that there were elements in item No. 3 of the cost that are independent of the amount of copper used, and, therefore, are independent of item No. 2 of cost. They then went on to show that maximum economy was secured when the variable element in item No. 3 became equal to item No. 2.

The constant element of the transmitting plant occurs in such things as the cost of the right of way, cost of necessary transformers, and a certain proportion of the cost of the supporting structure. The greater part of the variable element lies in the weight of conductors used in transmission, and a much smaller element in the cost of necessary insulation.

It follows, therefore, that if we design a transmission plant for maximum economy, the percentage increase in cost of power at the receiving end over the cost of power at the transmitting end is at least double the percentage loss. For instance, if we find that 10 per cent. loss, in a given transmission proposition, gives maximum economy, the cost of power at the receiving end must be at least 20 per cent. greater than at the generating end.

In order to make electric transmission of power reliable, it is necessary to provide a certain excess capacity in the transmission line or lines, and to provide spare apparatus for use in case any part of the system becomes damaged. The cost of these spare parts,—the price of reliability,—should be added to the cost sufficient under normal conditions, and forms another item of expense. The amount of this item is dependent, of course, upon the importance of the service and is governed by local conditions.

The expense of the necessary right of way is another element in the cost of transmission, which is dependent upon local conditions. It is evident that a right of way between Niagara Falls and Buffalo, for instance, would be much more expensive than that through a

mountainous district of an out-of-the-way part of the country.

The problem of electric transmission is, therefore, largely a commercial problem. From the above analysis we might expect that the transmission of power would be most highly developed in the localities where any or all of the following conditions exist:—First, where competing power is expensive from any cause, such as high-priced fuel, scarcity of water, expensive labour, or poor transportation facilities. Second, where water powers are abundant and easily developed and where, therefore, the raw material of the enterprise is cheap. Third, where the demand for power is extensive.

Along the Pacific Coast of the United States these conditions are closely met. Water powers are there abundant, fuel is expensive, both on account of its scarcity and difficulty of transportation, and the market for power is extensive. All along the coast from southern California to northern Washington, and even into British Columbia, the energy of the mountain streams is a commodity that can be purchased in almost any city and town and in many of the villages.

The "white coal" of the Alps, so-called from the snow caps which form the sources of the mountain streams, is in great demand in Switzerland and the neighbouring Alpine countries. There is now under serious consideration a scheme for transmitting to Paris power developed from these mountain streams of the Alps, about 300 miles distant. It seems probable that this transmission will be one of the engineering realities of the near future.

The development of Niagara Falls is too well known to discuss at length, but the region is one where coal is not expensive and still electrically transmitted power finds an almost unlimited market. The distance, however, to which power in the northern part of the State of New York can be transmitted and sold at a profit is not so great as it would be in California or in South Africa, where fuel is much more expensive and transportation facilities are inadequately developed.

II.—ENGINEERING LIMITS

The present state of the art of long-distance transmission is the result of evolution. No engineer is prepared to believe that this process of evolution has just begun and that epoch-making and revolutionary improvements in the art of long-distance transmission are impending, as some electricity-in-its-infancy paragraph writers would have us believe. On the other hand, no engineer is prepared to believe that the process is complete, or that the art has reached its acme of perfection. Somewhere between these two extremes lies the truth. It is fair to assume that as perfection is more closely approached those limitations of a technical nature, beyond which we cannot see our way clear to advance at present, will be gradually extended by the experience of the future to a point higher than that attainable now.

The principal thing which at present limits the distance to which power can be transmitted is voltage, or rather insulation. The amount of copper, which constitutes a large proportion of the total cost of any given transmission scheme, is directly proportional to the square of the distance and the amount of power transmitted, and is inversely proportional to the square of the voltage used and the loss that takes place in the conductors. Algebraically expressed, this law is:—

$$\text{Weight of copper} = \frac{\text{K. W. x miles}^2}{\text{Loss x voltage}^2}$$

It is evident, therefore, that if we could increase the voltage indefinitely, we could increase the transmission distance indefinitely; but we soon come to a limit beyond which we find it is impossible to increase the voltage. Just what this limit in voltage is at present is somewhat a matter of individual opinion, and what it will be in the future involves an exercise of prophetic vision which it is beyond the scope of this discussion to assume.

The highest voltage actually in use at the present time is about 55,000. This voltage is used in the Canon Ferry-Butte transmission in Montana, a distance of about 65 miles, and in the

Shawinigan-Montreal transmission in Canada, a distance of about 80 miles. Higher voltages have been proposed, and in some cases have even been prepared for, in the design of lines and transformers; but up to the present time none higher than 55,000 volts has been put into successful commercial operation.

The most serious difficulties encountered in increasing the voltage of transmission are:—

1.—Difficulty in maintaining perfect insulation.

2.—Difficulty in obtaining proper protection from lightning discharges and other static troubles.

3.—Loss of power due to brush discharges from high-tension conductors.

4.—Deterioration of the high-tension conductors, due to the fact that compounds which attack the metal are formed by the action of these brush discharges upon the atmosphere.

As before stated it is beyond the scope of this paper to place a future limit to voltage increase, but present indications are that no increases of a revolutionary character may be expected in this direction,—at least not in the immediate future.

Another condition which falls under the head of an engineering limit is occasioned by what the electrical engineer calls regulation. In order to give good service, the voltage at the consumer's apparatus should be practically constant under all conditions. If the voltage is not constant, there is a variation in the illumination of the customer's lamps and in the speed of his motors which he is apt to find exceedingly annoying, and which, if not corrected, will lead him to seek some other source of light and power.

Now, in order that the voltage shall be constant at the receiving end of a transmission line,—which usually means practically constant on the consumer's apparatus,—the voltage at the generating end must increase as the load transmitted increases. The percentage increase in voltage at the generating end between no load and full load on the transmission line in order to maintain a constant voltage at the receiving end is called regulation. Regulation is a function of the loss which takes place in any transmission; the greater the loss, the poorer the regulation.

In very long transmission lines, in order to obtain maximum economy, the loss increases with the distance, and usually we find that in order to obtain maximum economy in long-distance lines there will be a regulation considerably worse than that demanded by good service. That is, if we could increase the loss in transmission over that fixed by the worst allowable regulation, the saving in the cost of the transmitting plant would overbalance the cost of additional power lost. For very long transmissions, therefore, Kelvin's law is ruled out by other considerations, and the cost of transmission is thereby made higher than if the law could be applied.

The question now naturally arises,—what is the maximum allowable loss that will not exceed the worst allowable regulation? This is a question of the character of service and load, the regulation of generator, the efficiency of the governing apparatus, and, to a coniderable extent, a matter of individual opinion. Probably no electrical engineer would care to recommend the installation of a transmission line in which he must generate 30 per cent. more volts at full load than at no load in order to maintain a constant voltage at the receiving end. The percentage loss which is entailed by a 30 per cent. regulation is a somewhat intricate function of loss, character of load, frequency, etc.; but in common practice, as it exists to-day, it would rarely exceed 20 per cent.

There are methods whereby this element of regulation can be eliminated,—for instance, the use of motor-generator sets at the receiving station, the speed of whose motors is practically independent of the voltage applied. This, however, means more apparatus, with additional cost, maintenance, and liability of breakdown to be balanced against the saving its use would accomplish in the cost of transmission.

The writer does not wish to have the reader get the impression from this dis-

cussion that it is always necessary to adopt a very high voltage for transmitting electric power. High voltages bring troubles of their own, and a large amount of such troubles can be avoided by using common sense in the selection of the voltage. A 10, 20 or 30-mile transmission can be carried out with voltages which are comparatively low and still not run the cost of transmission to a prohibitive figure.

A very handy rough-and-ready rule for estimating the cost of copper in any given transmission is this:—If the voltage of transmission in thousands of volts is equal to the miles of distance, the cost of copper for that transmission, assuming copper at 20 cents per pound, will be very close to $5 per KW transmitted. This is based upon the assumption that the loss is 10 per cent.

For other losses, other distances, and other voltages the formula on page 131 can be readily applied to obtain the cost of copper. For instance, if the miles of transmission are double the number of volts expressed in thousands, the cost of copper will be four times that stated above, or $20 per KW, for a 10 per cent. loss. If in this case the loss be increased to 20 per cent., the cost of copper will be one-half, or $10 per KW.

The total cost of any transmission scheme, including cost of generating station with all appliances, cost of prime movers and buildings, cost of receiving station, will probably be at least $75 per KW, and usually much more. It is evident, therefore, that we can keep the proportionate cost of the transmitting plant comparatively low by adopting moderate voltages, unless the distance of transmission becomes considerably greater than that which the engineer has usually to provide for.

Another class of limiting conditions in long-distance transmission, which may be mentioned in passing, is what may be called legal restrictions. The possibility always exists that laws will be passed to limit voltage on the score of the dangers to a community. In the United States it has so far been found unnecessary to invoke the aid of the law. Of more importance are the rules which have been and will, in the future, be established by the various boards of fire underwriters. A rash and ill-considered rule, which might be made and enforced by the fire underwriters, might prove exceedingly disastrous to the art of long-distance transmission. That proper precautions should be taken to protect life and property admits of no discussion. The remedies of such evils lie in regulation and not in strangulation.

While in the foregoing we have a rather brief and purely abstract analysis of some of the main elements entering into the problem of high-tension transmission, the assumption and solution of one or two concrete examples may assist to a more thorough understanding of the matter.

Suppose, therefore, that we assume a 25-mile transmission at 25,000 volts. Assume copper at 20 cents a pound, and let the interest, depreciation, and maintenance, and taxes, on the cost of the copper in the transmission plant be taken at 12 per cent. Assume further that it costs $20 per KW per year to generate power. The question in which both the promoter and the engineer of such an enterprise is particularly interested is, what is the cost of transmission? Given the assumptions above, this question can be answered at least partially. A complete answer will require more complete data.

We have already seen from the approximate rule on this page that, assuming conditions as above, the investment in copper is $5 for a loss of 10 per cent., and that for other losses the investment is in inverse proportion. We have seen also that maximum economy will be obtained when the annual interest charge on this investment is equal to the annual value of power lost. At a loss of 10 per cent. these two elements are not equal; but we find that by reducing the loss to about 5½ per cent., thereby raising the investment in copper to about $9, the two elements became very nearly equal. One becomes 12 per cent. of $9, or about $1.08, and the other becomes 5½ per cent. of $20, or $1.10. The cost of power, therefore, at the receiving end

will be at least 11 per cent. greater than at the generating end.

This is as far as our answer can go. The amount that the 11 per cent. will have to be increased to obtain the actual figure will depend upon the additional investment necessary for transformers, right of way, etc., as well as upon the load factor. By load factor is meant the ratio of the average to the maximum load on the system.

Investment and, therefore, interest, etc., depends upon maximum load. This item is active twenty-four hours per day and every day. The returns on the investment or the amounts received for power sold depend very largely upon the time during which power is used. If, for instance, the power can be used only during two hours of the twenty-four, it is evident that the proportionate cost of transmission must be higher than if the power were used the whole twenty-four hours. Neither has the figure given above taken into account the necessary investment for spare lines, etc.; all these elements tend to increase, and none to decrease, the 11 per cent., as figured above.

The writer has mentioned the proposed transmission from the Alps to Paris. A few figures showing the minimum cost of transmitting power this distance,—300 miles,—may be of interest. The first question is what voltage and loss to use. Assume first that the consideration of regulation will limit loss to 15 per cent. The regulation imposed by this loss depends upon the frequency chosen and the character of the load, but probably will be not less than 25 per cent. Fifty thousand volts delivered in Paris, therefore, will mean the use of a voltage higher than any in use at present, but still a voltage within the bounds of reason.

Applying the rule and formula given on page 131, we find that the cost of copper for these conditions is about $120 per KW,—copper at 20 cents a pound. Assume that additional investment per KW for right of way, transformers, supporting structure, etc., will be as much more, making a total investment of $240 per KW for transmission alone. At 12 per cent. the annual cost will, therefore, be $28.80. Add to this the value of the power lost per KW transmitted,—15 per cent. of, say, $20,—and we have a total of about $32 per KW. This will be the cost per year to transmit one KW, provided we assume a load factor of one.

This figure is, of course, subject to wide correction, as the assumptions made may vary from the truth. The examples are given to illustrate method rather than to give actual figures. In the last example it will be noted that Kelvin's law does not apply. If a worse regulation and a higher loss were allowable, the cost of transmission could be considerably reduced.

The limitations that have been treated in this discussion up to this point are those which affect the design of the transmission plant. As soon as we come to the matter of operation another type of limitation enters the problem. No matter how well designed a transmission line may be, difficulties will arise in operation that it is impossible to foresee or take care of in the design. While it will be impossible to mention all of the troubles to which the operator of a high-tension transmission line is subject, an account of a few of them will probably be of interest.

While perhaps not the most frequent, certainly the most exasperating trouble with which a transmission manager has to contend is malicious interference. It is a difficulty over which an improvement in methods has little effect, and an improvement in apparatus none. It is a difficulty not due to the weakness of the line, but to the frailty of human nature. Sometimes such trouble arises from an actual intention to do harm, as, for instance, a feeling of spite on the part of a discharged employee. More often, however, the culprit does not realise the amount of damage and inconvenience his careless act may cause. All that the hunter finds is that the insulator makes a good target for his rifle, and all that the small boy knows is that a piece of baling wire over the line will make a most interesting display of fireworks.

Neither the hunter nor the small boy

realises that his act may throw a whole city into darkness or stop trolley cars miles away. Whether done maliciously or carelessly, detection is difficult. A transmission line is open to attack anywhere along its entire length. Often these lines are run through a sparsely settled country, and a patrolling sufficient to prevent all mischief is practically impossible.

One notable instance in which malicious interference became a serious problem occurred in the high-tension transmission plants which take power into the city of Mexico. In that region the favourite implements for causing trouble on the lines were the leaves of the maguay plant, a sort of cactus. The leaves of this plant are very largely composed of water, and are, therefore, good conductors of electricity, at least for the high voltages. The native's chief delight seemed to be in throwing these leaves over the high-tension lines and watching the resultant fireworks. All other expedients failed, and it finally became necessary to ask the Government to detail a cavalry guard to patrol some of these transmission lines, with orders to "shoot to kill" anyone found interfering with them.

Another Mexican expedient is most ingenious, and certainly shows a sense of humour that one would hardly expect to find in a Mexican. A native was caught "red-handed" in the act of throwing a maguay leaf upon one of the transmission lines. He was immediately taken before a Mexican judge, and the case was clearly proved against him. The judge sentenced the culprit to one year in jail, and then suspended the sentence,—and this is where he displayed real genius,—until the next maguay leaf should be thrown upon the transmission line,—no matter by whom. This practically gave the Mexican the choice of going to jail for one year or constituting himself a committee of one to patrol the line and see that no further interference occurred.

In connection with this the experience of one of the Westinghouse Company's engineers is brought to mind. A certain South American government was developing a water-power for the purpose of lighting an adjacent town. Before the plant had been accepted a revolution broke out, and the transmission line, being a Government institution, was fair game for the revolutionists. First they tried dynamite on the power house; but a strict guard was kept after the first attack, and further attempts in this direction were thus prevented. A new method of attack was to cut the transmission lines. The plant was used for lighting only, and the current was shut off during daylight hours, at which time this cutting could be done with safety. After fixing up one or two cuts, however, the engineer's next move was to keep the power on the line continuously. The effect was immediate. To quote the words of the engineer's report literally:—"Next morning there were two new faces in Hell for breakfast."

Man, however, is not the only animal guilty of interfering with transmission lines, although he is probably the only one that does it with malice aforethought. In some localities large birds are a considerable source of trouble. In a number of instances short circuits have been due to cranes getting tangled with the high-tension wires. In other sections owls seem to be large enough to get between the transmission conductors. On the Niagara-Buffalo transmission line there were two occasions when a cat,—not the same in both cases, however,—managed to short-circuit the line by getting its body between adjacent conductors.

Lightning is another difficulty with which the operating engineer has to contend. Although arresters of greater or less efficiency have been devised, absolute protection from the effects of lightning is impossible in the present state of the art. During a thunderstorm the manager can never feel absolute assurance that his apparatus is safe from destruction by lightning. Electrical apparatus is somewhat peculiar in regard to damage by lightning in that a direct stroke is not necessary. The electrical pressure from the dynamo is constantly present, and it only needs a temporary break in insulation which

may be made by a " side flash " to give it the opportunity of flowing in forbidden paths and so causing damage. A partial analogy to this condition may be found in a river kept within its banks by levees. A rift, in itself almost beneath notice, becomes a menace as soon as the pressure of water from the swollen river bears upon it.

It is essential that the transmission line manager shall have means of communication between the different parts of his system. The usual method of securing it is by means of a telephone system, the conductors of which are usually on the same poles as the transmission wires. Proper maintenance of this communicating system is another difficulty that confronts the manager. The proximity of the high-tension conductors to the telephone wires does not help matters. The importance of making such a disposition of the wires that interference will be a minimum is obvious.

Many of the difficulties mentioned above can be foreseen, and, in a measure, provision can be made for them. For instance, interference by the malicious and careless can be remedied to a considerable extent by elevating the transmission conductors. But the higher the conductors are placed, the more expensive is the construction. The question is, how far can we afford to elevate the wires in order to obtain the additional immunity from interference that such elevation will give? Each case has a different answer. It is the duty of the engineer not only to be familiar with the troubles that have occurred in transmission plants and the troubles that are liable to occur in any specific plant, but also to be familiar with the remedies for these troubles so far as they exist.

It is not a simple question, therefore, which the engineer has to decide when he specifies a transmission scheme. The elements that enter his problem are many and extremely varied in character. The items that the engineer must consider before an intelligent answer can be given to the promoter with a transmission scheme form an interesting list. They are,—

Voltage to be adopted.
Frequency to be adopted.
Regulation to be adopted.
Efficiency to be adopted.
Prices of copper.
Cost of poles or other supporting structure.
Cost of labour.
Cost of transportation.
Price of coal.
Cost of power at generating end of line.
Value of right of way.
Interest rate on investment.
Proper charge for maintenance.
Proper charge for depreciation.
Taxes.
Load factor, i. e., ratio of average to maximum load.

All these factors the engineer must bear in mind. It is his business to know what influence a variation in any factor will exert in the final result or in any other factor. It is his business to know not only the general considerations which enter his problem, but also to make himself thoroughly acquainted with the special considerations which invariably enter any specific case. The fact, too, that wide variations of opinion exist on some of the points, even among those best qualified to judge, does not lighten the burdens of the high-tension engineer.

To observe the tendencies of present practice; to become acquainted with those things that are proving successful in practice, as well as those that may be expected to succeed in theory; to formulate laws to connect the seemingly discordant elements of his problem; in short, to bring harmony out of apparent chaos, these are the functions of the electrical engineer.

TRANSFORMERS FOR LONG-DISTANCE POWER TRANSMISSION

By J. S. Peck

IN the fall of 1892 the first long-distance plant in America was installed in California for transmitting power from a waterfall on the San Antonio Creek to the cities of Pomona and San Bernardino. The transmission was at 10,000 volts, and the maximum distance of transmission twenty-eight miles, the current being used almost entirely for incandescent and arc lighting.

For stepping-up the low voltage of the generator to the pressure required for transmission, twenty 5-KW transformers were used. Each transformer was wound for 500 volts, and the line pressure was obtained by connecting the twenty transformers in series. Similar arrangements of transformers were used for stepping-down the line voltage to values suitable for use in the cities.

At the time the Pomona transformers were designed, little was known regarding the construction of high-voltage apparatus, and the perplexities and difficulties encountered in the design and manufacture of these transformers can scarcely be appreciated by the engineer of to-day. The care with which the designs were worked out is shown, however, not only by the long and continuous service rendered by these transformers, but by the fact that two of their most important features, namely, oil insulation and the "shell" type of construction, are retained in the most improved designs of to-day.

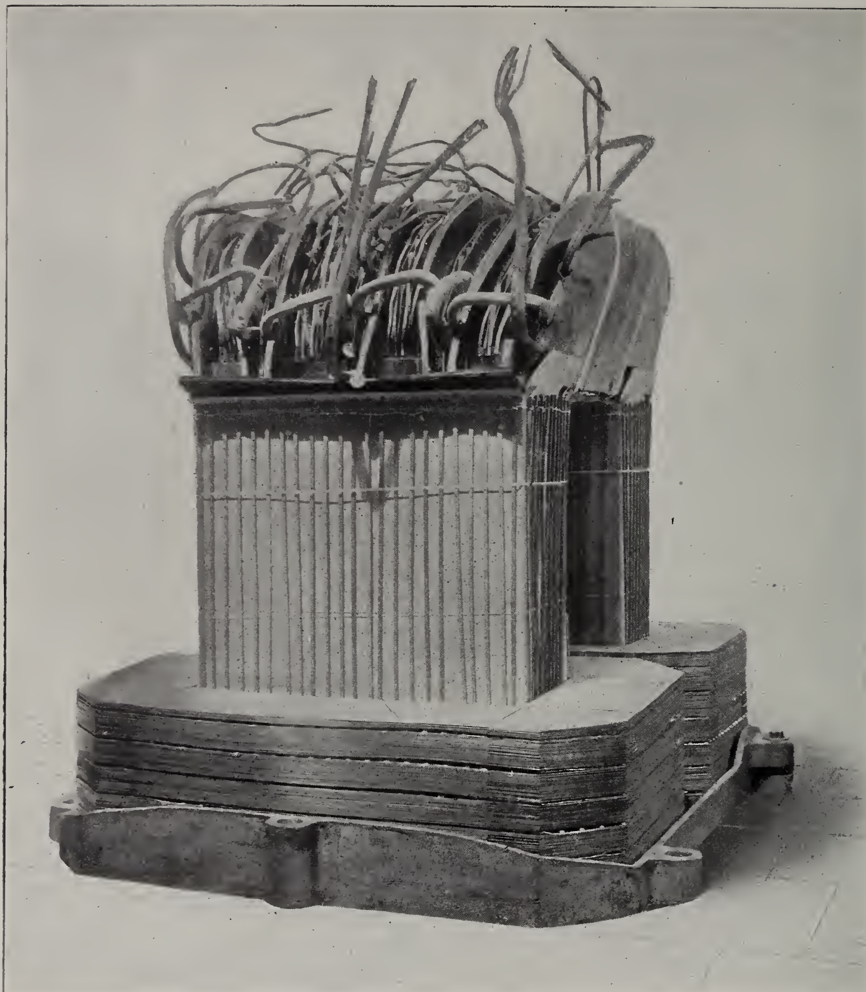
The success of the Pomona plant, followed closely by the introduction of the alternating-current motor, gave a great impetus to long-distance transmission work, and in a short time power transmissions were being projected everywhere. For the increased distances of transmission it soon became apparent that much higher voltages would be required than were used at Pomona. Improved manufacturing facilities and increased experience in designing made possible the construction of large transformer units wound for the full line voltage, and as a large unit could be manufactured for less cost per kilowatt than a small one, the series arrangement of many small transformers was superseded by an arrangement of large units, wound for the full line voltage.

The enormous increase in the transformer business which has followed the installation of the Pomona plant, and the rapid advance in voltage and in size of transformer unit, are clearly shown in the table on this page,* which is made

OUTPUT OF HIGH-VOLTAGE TRANSFORMERS FROM 1892 TO 1903

YEAR	Number of Transformers	Output KW	Maximum Voltage	Maximum Capacity KW	Average Voltage	Average Capacity KW
1892....	65	406	10,000	10	9,070	6 25.
1893....	19	272	3,000	18.75	2,500	14.4
1894....	68	1,720	10,000	100	3,600	25.3
1895....	78	4,215	10,000	200	7,000	54.0
1896....	150	12,820	15,000	750	9,620	85.0
1897....	165	21,091	30,000	850	10,600	128.0
1898....	387	49.719	30,000	500	15,300	129.0
1899....	662	119.492	33,000	1,875	12,800	180.0
1900....	492	171,646	50,000	2,750	17,000	350.0
1901....	997	201,475	50,000	1,000	12.400	202.0
1902....	985	248,982	50,000	2,200	16.700	253.00
Total	4,068	831,838	......	.....	......	204.

*When this article was prepared the transformer data for the year 1903 were not available



METHOD OF BUILDING UP THE SHEET STEEL CORE OF A LARGE TRANSFORMER

up from the records of one of the largest electrical manufacturing companies. The transformers included in this list are all used for high-voltage transmission, and it is of interest to note that the four thousand transformers represent an aggregate capacity of 800,000 KW,—over 1,000,000 H. P.,—the average size of unit being 200 KW.

A history of the ten-year development of the high-voltage transformer would show a most interesting process of evolution; but it is the modern transformer with which the practical engineer is most deeply concerned, and interesting as the history of this development would be, it is thought that a description of the transformer of to-day will be of greater value to the engineer.

High-voltage transformers may be divided into three classes:—

1.—Oil-Insulated, Self-Cooling.
2.—Oil-Insulated, Water-Cooled.
3.—Air Blast.

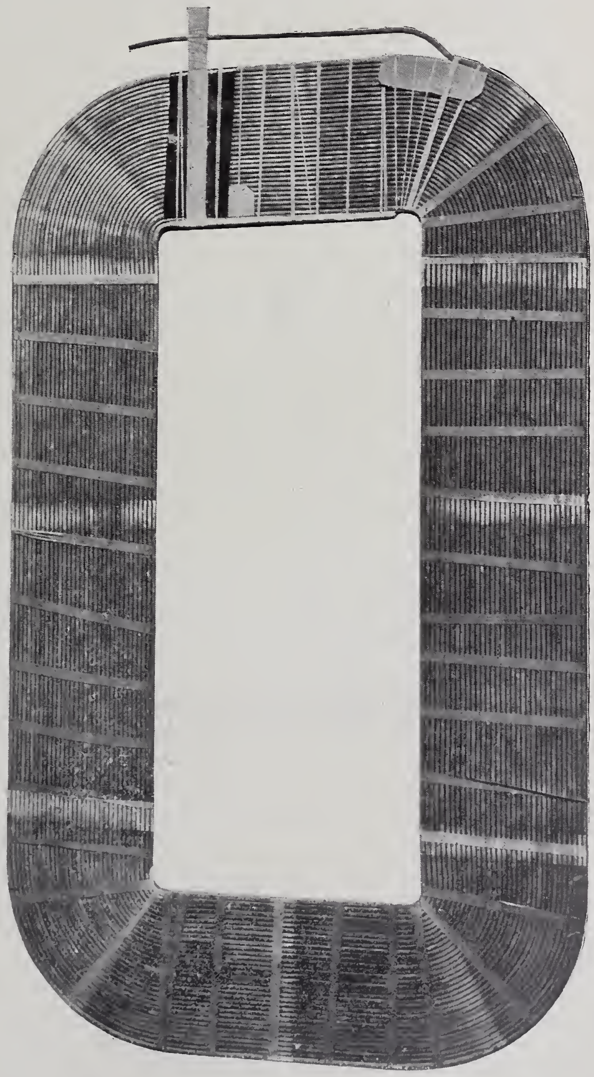
The general form of internal construction is the same in the three classes, but suitable modifications are made to accommodate the different insulating and cooling mediums. The transformer windings are composed of a number of

thin, flat coils placed side by side and separated by insulating material. The coils are made up of cotton-insulated rectangular wire, wound usually with but one turn per layer. After winding they are dried in a vacuum oven at a comparatively high temperature to abstract all the moisture, and are then treated with a compound which prevents the re-entrance of moisture and adds greatly to their mechanical strength. The treating process is repeated several times to insure a heavy, uniform waterproof coating, and after this treatment the coils are wrapped with insulating material and assembled with suitable ventilating ducts and insulating barriers between them. The ventilating ducts permit the cooling medium, oil or air, to come into close proximity to all parts of the winding and thus prevent undue local heating.

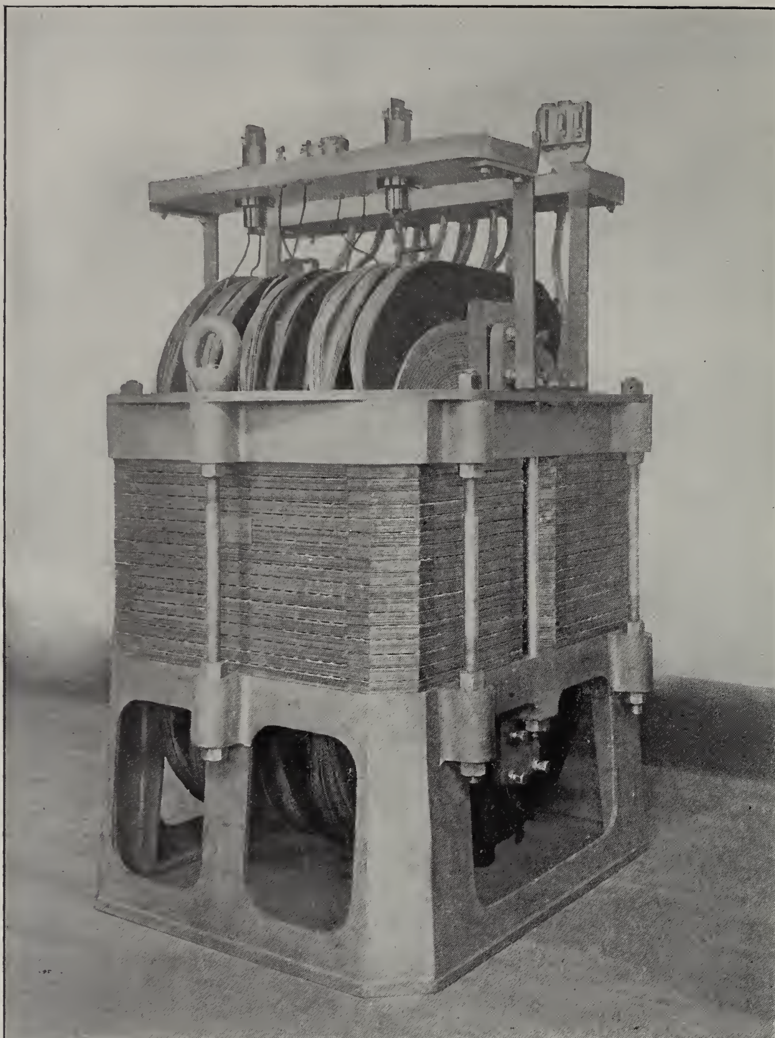
By winding the coils with but one turn per layer, every turn may be isolated from every other one and insulated to any extent desired. This form of coil-winding is of great value in high-tension transformers, as it has been found in practice that excessive voltages may be concentrated upon a few turns of one coil, and a break between turns is fatal to the whole transformer.

The sub-division of the coils permits the interlacing of primary and secondary windings, an arrangement essential to close regulation, especially when inductive loads, such as motors or arc lamps, are supplied. It is also possible where the coils are thus subdivided to arrange the primary and secondary in two or more parts, which may be connected in series or multiple for different voltages.

While the proper proportioning of the active elements (coils of copper and core of sheet steel) is one of the essentials in transformer design, the proper selection, treatment and arrangement of the insulating material requires even greater skill and wider knowledge than does the proportioning of copper and sheet steel. This is due, in part, to the fact that copper and steel are strong mechanically, are good conductors of heat, and



A TYPICAL COIL FOR A LARGE HIGH-VOLTAGE TRANSFORMER



A 950 KW 50,000-VOLT WATER-COOLED TRANSFORMER. NOTE THE SIZE AND THICKNESS OF THE INSULATING BARRIERS BETWEEN THE HIGH AND THE LOW-TENSION COILS

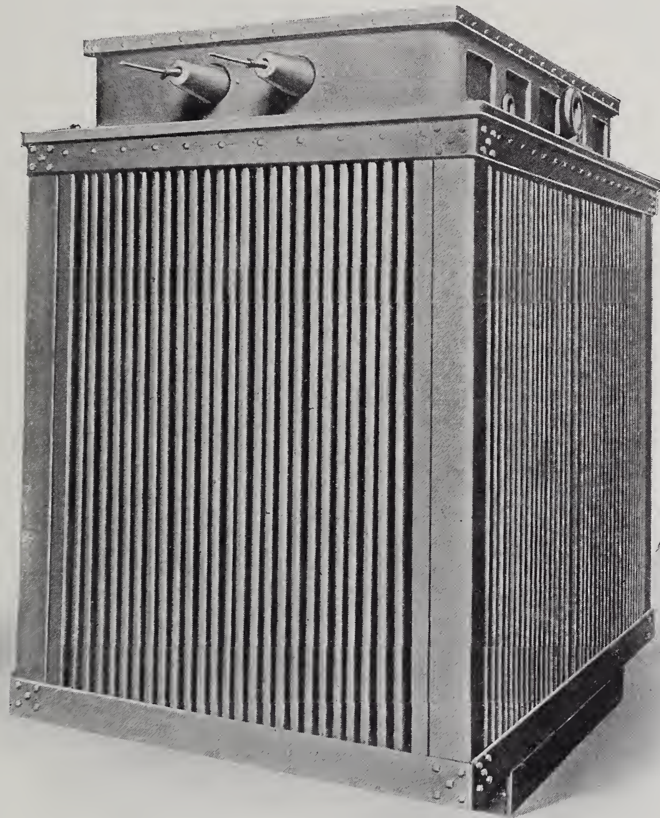
are uniform in their electrical characteristics. Insulating materials, on the other hand, are weak mechanically, are poor conductors of heat, and their electrical characteristics are subject to the widest variations, due to slight differences in their physical condition. Wood, for example, when perfectly dry, is an excellent insulator; but when damp or imperfectly cured, it becomes a conductor, and cases have been known where a certain voltage has broken through a thickness of several feet of green wood, while an inch thickness of the same material, properly cured, has successfully withstood the same pressure.

Almost all insulating materials are subject to similar variations in insulation strength, and the greatest care is required in their preparation as well as in the prevention of deterioration which would be caused by the absorption of moisture or other conducting mate-

rial during manufacture or installation.

After the coils have been assembled and properly insulated, the sheet iron core is built up by hand about the coils and ventilating ducts are provided at frequent intervals throughout the structure, serving to maintain it at a uniform temperature. When the laminations are all in place, the end castings are put on and the core is bolted up solidly. The necessary terminal blocks are next secured in place, the coil leads connected to the proper terminals, and the construction of the transformer is complete. In the air-blast type of construction the castings which hold the laminations form the case or housing, and no other covering is required; but in the oil-insulated types an outside case is necessary for holding the oil.

The losses in a transformer are of two kinds,—the copper loss, due to the passage of current through the coils, and the iron loss, caused by the reversing of the magnetic flux through the core. These losses appear as heat, and suitable precautions must be taken for the disposal of this heat. In a 500 KW transformer having an efficiency of 98½ per cent., there is a loss of 7½ KW (10 H. P.), which is equivalent to the heat liberated by one hundred and fifty 16-candle-power lamps. If the apparatus is not suitably ventilated or provision is not made for carrying away this heat, the insulating material will be rapidly carbonised and the transformer soon destroyed.



THE CASING OF A 500 KW SELF-COOLING TRANSFORMER. NOTE THE LARGE AMOUNT OF COOLING SURFACE OBTAINED BY CORRUGATING THE SIDES OF THE CASE

STEP-DOWN OIL-INSULATED WATER-COOLED TRANSFORMERS,—1870 KW,—11,000 TO 2200 VOLTS, AT THE NEW CARBIDE WORKS AT NIAGARA FALLS, N. Y.
MADE BY THE GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y.

Two general methods are in use for disposing of this heat. One is to force a blast of air through the transformer; the other is to immerse the transformer in oil, then cool the oil by means of a case provided with large radiating surface, or by circulating water through coils immersed in the oil.

In the transformer the function of oil is to insulate and to cool. As an insulator, oil has a strength several times that of air, and is of particular value for the insulation of exposed surfaces which in air under very high voltage strains act almost as conductors. The fluidity of the oil also gives it an advantage over solid insulating material, in that it is self-healing and offers the same insulation strength after a discharge as before. It is also of value for sealing in cracks or openings which may be left in the solid insulating material.

As a cooling medium, oil acts as a conveyor of heat rather than as a conductor. Coming in contact with the active parts of the transformer it is heated, rises to the top, flows over the sides, and, coming in contact with the cooling surfaces, sinks and rises again past the heated surfaces. Thus a rapid circulation is automatically established, and the heat is conveyed from the active parts of the transformer to the surfaces provided for its dissipation.

The specific heat of oil per given volume is very great as compared with air, and on account of the great fluidity of oil it will pass through comparatively small ducts, and though travelling at a much slower rate than is required of the air in an air-blast transformer, it produces very effective results, with little chance of local heating.

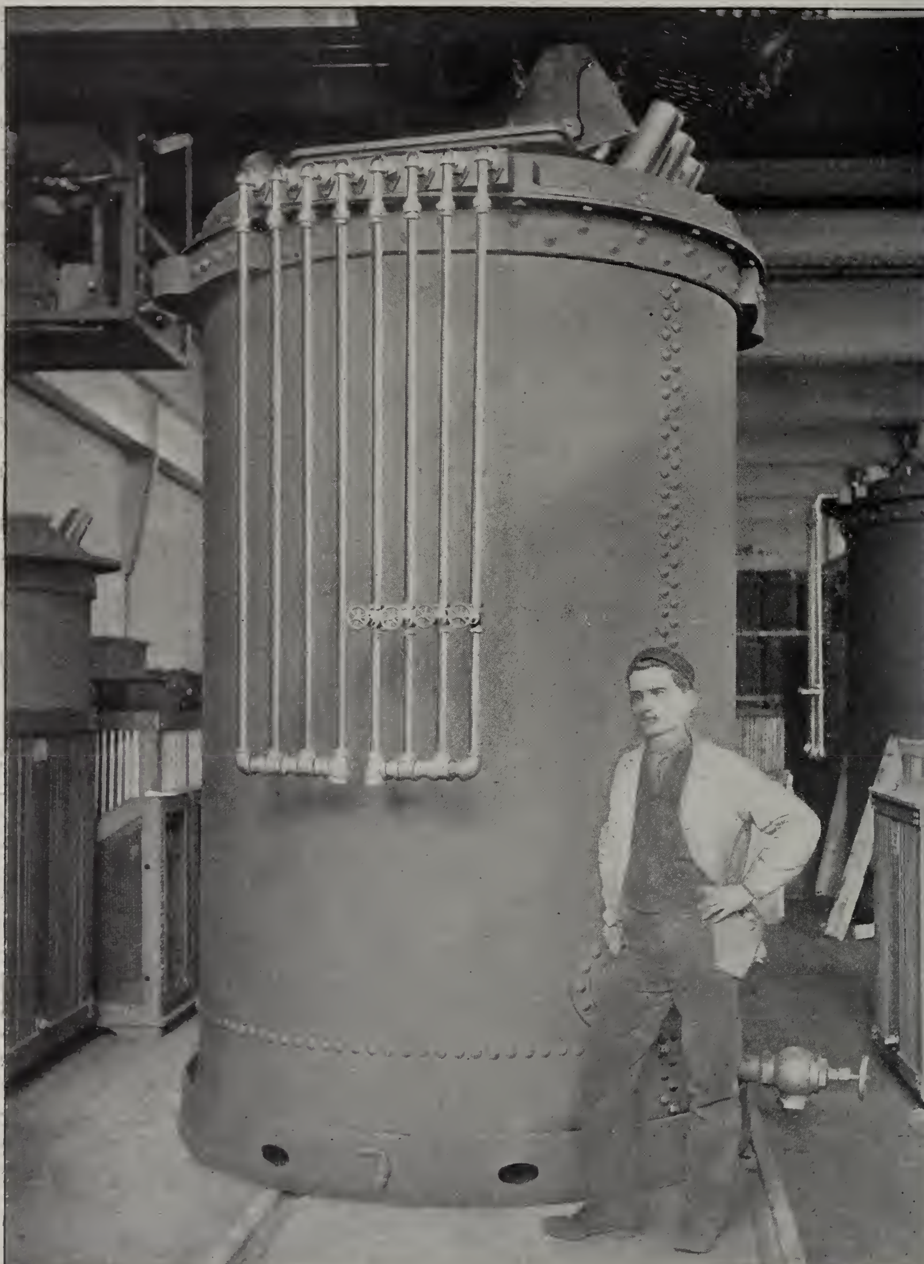
A mineral oil is used and great care is taken in its manufacture to insure freedom from acid, alkali, or water, as it is found that a fraction of one per cent. of water added to pure oil will reduce its insulation strength by more than 50 per cent. Fortunately, this rate of reduction is not a constant one. The oil should have a high fire test, low viscosity, and low rate of evaporation.

In the oil-insulating, self-cooling transformer the cooling is effected by means of the outside case which is designed with a large amount of radiating surface exposed to the outside air. A number of different forms of case have been devised, but the one giving the best satisfaction and now used almost exclusively, except for transformers of very small size, is made of heavy sheet metal, corrugated in such a manner as to greatly increase the area of its sides. This sheet iron case is mounted in a suitable framework, which is ordinarily of angle-iron construction. The top of the case is provided with a cast iron or sheet iron cover through which the leads are brought out.

The self-cooling transformer has a distinct advantage over all other types in that no extraneous cooling devices are required, and, after being installed, no attention need be given it. For units not exceeding 500 KW, particularly when located where they cannot be frequently inspected, the self-cooling transformer is used almost exclusively.

The immense amount of radiating surface required for disposing of the heat generated in a large transformer limits the capacity for which this type can be built economically to about 500 KW, so that for larger capacities the oil must be artificially cooled, and for this service water-cooling has been universally adopted.

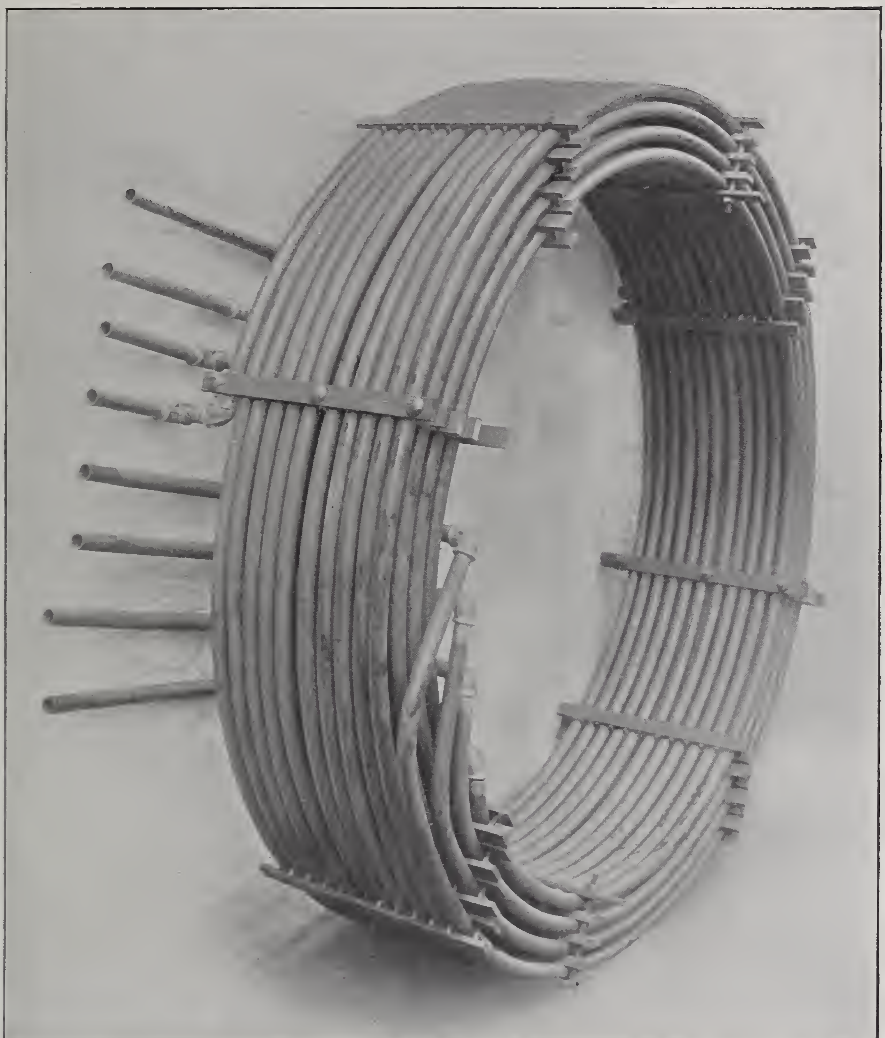
Several different methods of water-cooling have been tried from time to time, but one system is now used almost exclusively. In this the transformer is placed in a boiler iron case, which rests on a cast iron bed-plate and is provided with a cast iron cover, through which are carried the terminals from the windings and from the cooling coils. The cooling is effected by circulating water through one or more spirals of brass tubing placed around the inside of the case below the surface of the oil. This gives a simple and direct method of disposing of the heat generated in the transformer, and after the flow of water has been properly adjusted, no attention is required other than an occasional inspection to see that the water rate is properly maintained. A comparatively small amount of water is sufficient for



THE CASING OF A 2250 KW WATER-COOLED TRANSFORMER. THE COOLING COIL TERMINALS ARE HERE CLEARLY SHOWN

cooling a large transformer; a 2000 KW unit, for example, requires approximately five gallons per minute.

It is customary to provide these transformers with thermometers for indicating the temperature of the oil and for sounding a gong as a warning, should the temperature of the oil exceed a predetermined value due to a change in the rate of flow of water or from any other cause. The sounding of the gong is accomplished by means of an electrical device. Gauges are also provided for indicating the height of oil in the case, and provision is made so that samples of oil may be drawn off from the bottom of the case for testing the quality of the oil.



COOLING COILS FOR A LARGE WATER-COOLED TRANSFORMER

While the oil used in transformers is not inflammable, and will not burn unless raised to a high temperature, the presence of a large body of oil constitutes, under certain conditions, a fire risk which cannot be ignored, and suitable precautions should be taken for dispos-

A 2100 TO 60,000 VOLTS TRANSFORMER, MADE BY THE STANLEY ELECTRIC MFG. CO., PITTSFIELD, MASS. THE TRANSFORMER IS SHOWN WITHOUT ITS CASE

ing of the oil in case it becomes necessary. This is usually done by providing a large drain pipe at the bottom of the case, which will rapidly empty the tank and carry the oil into a sewer or into a pit suitably located and arranged for its reception.

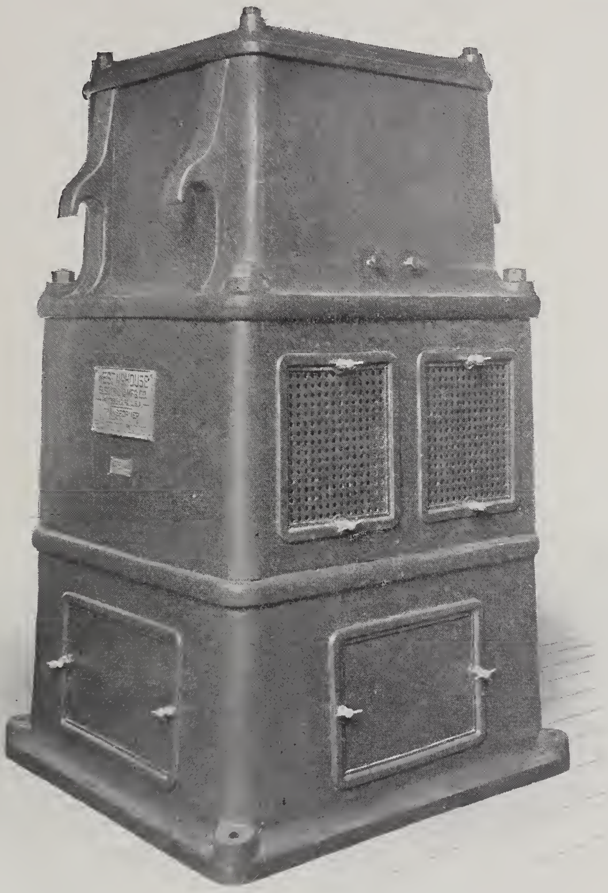
Another ingenious method lately devised consists in bringing out from the highest point in the cover a large pipe which is connected to a sewer or suitable storage tank, while at the bottom of the case another pipe connects to the water mains. In case of fire the connection to the water main is opened and the oil driven out of the pipe at the top of the case, which is left full of water. When the water is withdrawn and the transformer properly dried out, it will probably be little worse for its wetting. This construction requires an oil tight cover as well as an oil-tight joint between case and cover.

The air-blast transformer, as its name implies, is one in which the cooling is done by means of a forced draught of air. The usual installation consists of a group of transformers placed over an air chamber in which a pressure slightly above that of the surrounding air is maintained by means of a suitable blower. The air which is admitted to the transformer through an opening in the top of the air chamber passes into

the base of the transformer, where it divides into two separate circuits, one through the vertical ducts between the coils, the other through the horizontal ducts in the iron core. Suitable dampers are provided in both coil and iron circuits for controlling the amount of air. A fan or blower is used which is designed to give a large volume of air at a low pressure. It is ordinarily direct-connected to a motor.

Aside from the outer case or housing, the construction of oil-insulated and air-blast transformers is quite similar, though in the latter type greater insulating distances and larger cooling ducts are required, so that for equal size and voltage the efficiency of the air-blast transformer is usually lower than that of the oil-insulated type.

It has been found that with the insulating materials now available it is difficult to manufacture commercially air-blast transformers for pressures higher than approximately 30,000 volts, so that the air-blast transformer is practically barred from transmissions over very long distances.



A 550-KW WESTINGHOUSE AIR-BLAST TRANSFORMER. 11,000 TO 390 VOLTS, 3000 ALTERNATIONS

A comparison of the three types of high-voltage transformers,—self-cooling, water-cooling, and air-blast,—shows that while for certain classes of service any one may be chosen, there is a field for which each is particularly well

ONE OF THE 1250-KW WATER-COOLED TRANSFORMERS SUPPLIED TO THE CANADIAN NIAGARA POWER CO., PETERBORO, ONT., BY THE GENERAL ELECTRIC CO., SCHENECTADY, N. Y.

suited. The self-cooling transformer for moderate-sized units of high and low voltage is particularly fitted for use in small sub-stations where no regular attendance can be given; the water-cooled transformer for units of large capacity and for any voltage is especially suited for very large stations where cooling water may be easily obtained; the air-blast transformer, for units of any size and for voltages not exceeding approximately 30,000, may be used for large stations where there is constant supervision and where the presence of oil required by oil-insulated transformers might be considered objectionable.

The transformer has long been known as the most efficient of all commercial apparatus. It may be said, in general, that the efficiency increases with the size of the unit, decreases with increase in voltage, and increases as the frequency is increased. Efficiencies of 98 per cent. are quite common on commercial transformers of large size, even though wound for comparatively high voltages and low

frequencies, while an efficiency of 98½ per cent. has been exceeded on a number of transformers now in commercial service. Full load efficiencies are, of course, referred to; but remarkably high values are also obtained at overloads and at small fractions of full loads.

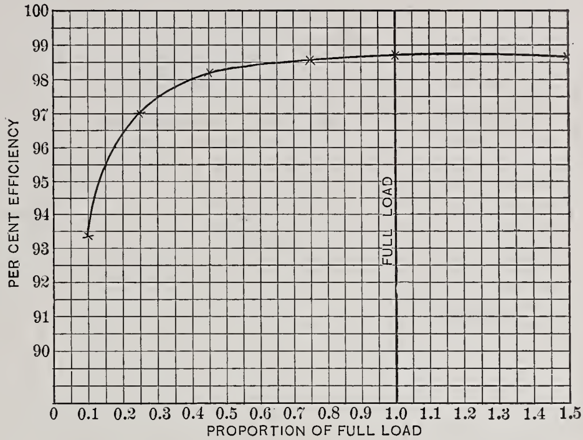


FIG. 1.—EFFICIENCY CURVE FOR A 2500-KW OIL-INSULATED WATER-COOLED TRANSFORMER, 45,000 TO 2400 VOLTS, 8000 ALTERNATIONS

Not only is the efficiency of transformers remarkably high, but the regulation, which is the drop in voltage from no load to full load, is extremely close, and while it varies somewhat with the character of the load supplied, it is, in general, closer than that of the apparatus in any other part of the system.

For long-distance transmission three-phase currents are used almost exclusively. In the majority of cases the generators are three-phase machines, but there are a number of plants where two-phase current is generated and special step-up transformers are used for changing from two-phase to three-phase.

In America it is customary to group together two or more single-phase transformers for use on polyphase circuits, while in Europe the polyphase transformer is extensively used.

Where three-phase current is generated and transmitted three transformers are usually employed. They may be connected in delta or in star, or with one winding in delta and the other in star. Methods of connecting transformers are shown in Fig. 3, where the generator voltage is assumed to be 1000 and the line voltage 10,000. With the delta connection each transformer is wound for the full voltage of the circuit to which it is connected, while with the star connection each transformer is wound for 58 per cent. of the voltage of the circuit.

In winding transformers for high voltage the star connection has an advantage, for by reducing the voltage on an individual unit it permits a reduction in the number of turns and an increase in the size of conductors, giving coils easier to wind and more simple to insulate. The delta connection has, however, a distinct advantage over the star or delta-star arrangement, for in case one transformer of a group of three

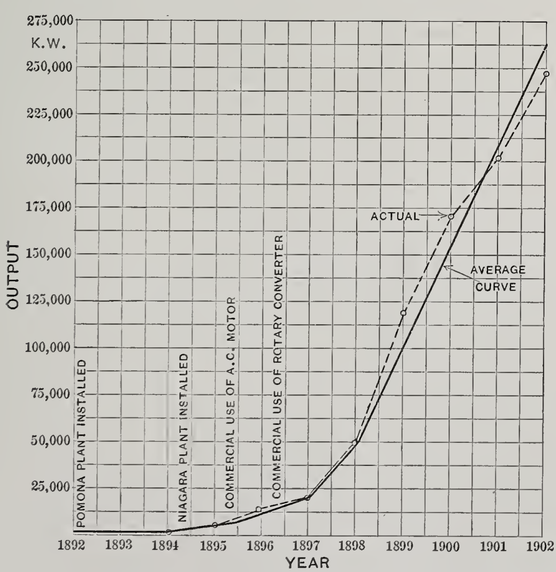


FIG. 2.—CURVE SHOWING OUTPUT OF HIGH-VOLTAGE TRANSFORMERS FROM 1892 TO 1903

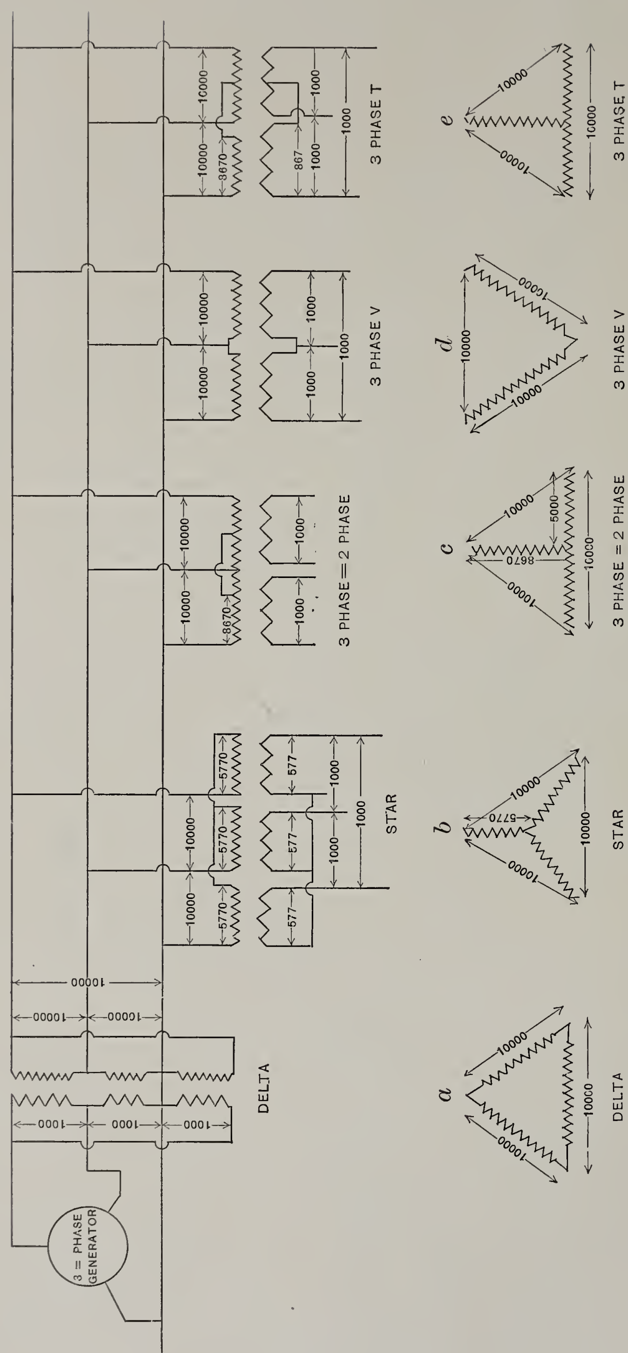


FIG. 3.—METHODS OF GROUPING SINGLE-PHASE TRANSFORMERS FOR POLYPHASE TRANSFORMATIONS

should become disabled, the two remaining ones will continue to deliver three-phase currents with a capacity equal to approximately two-thirds of the original output of the group.

Quite frequently it is desired to begin the operation of a transmission system at a comparatively low voltage and later to change to a much higher value. In such cases the transformers may be connected at first with both windings in delta, and at a later date the high-tension windings may be changed to star with a resultant increase of 73 per cent. in line voltage. For example, transformers wound for 1000 to 19,000 volts, with both windings connected in delta, will give a line voltage of 19,000, but with low-tension windings connected in delta and high-tension windings in star, the line voltage will be increased to 30,000.

Where two-phase current is generated and it is desired to transform it to three-phase current, or when it is desired to change three-phase current to two-phase current, two transformers are used with the well-known connection for this transformation. This method of connecting and the resultant voltages obtained are shown at *c*, in Fig. 2.

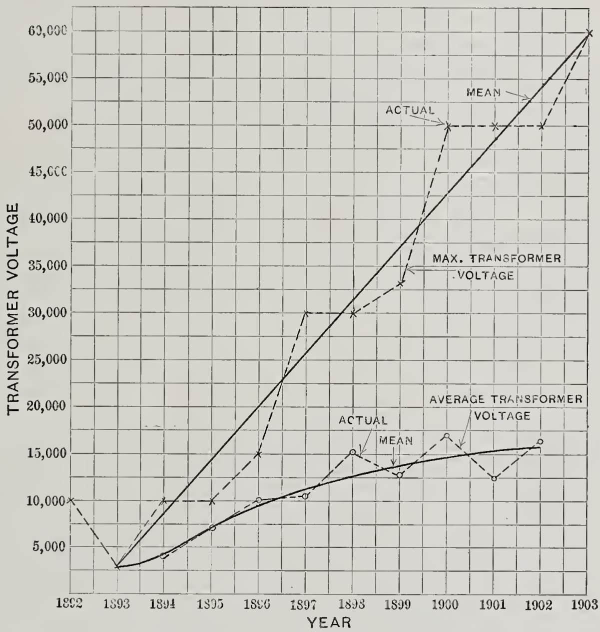


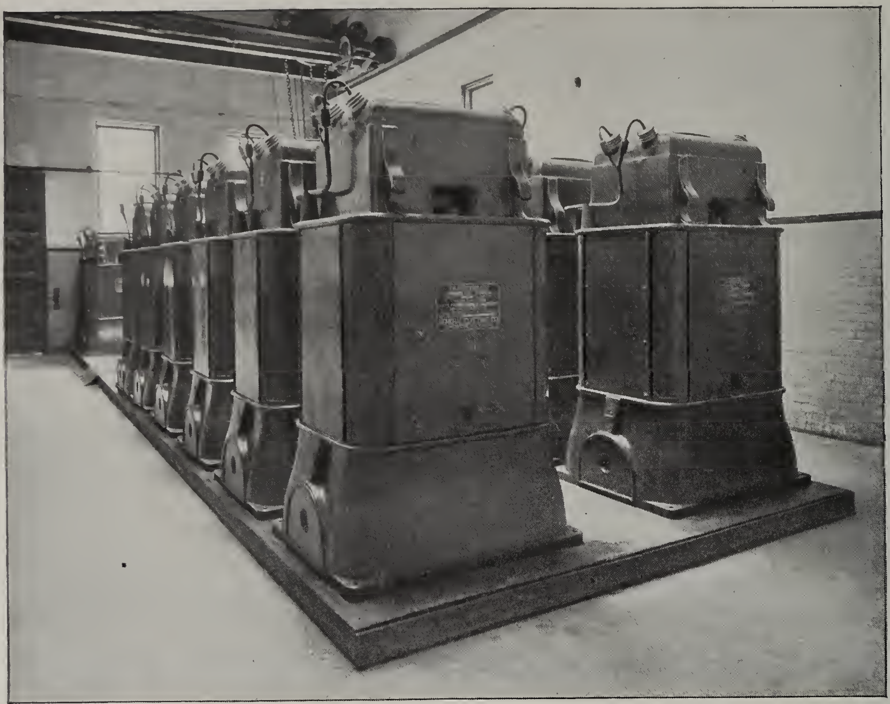
FIG. 4.—CURVES SHOWING MAXIMUM AND AVERAGE TRANSFORMER VOLTAGES FROM 1892 TO 1903

Three-phase to three-phase transformations may also be made with two transformers, by connecting in *V* or in *T*. The *V*-connection is simply the delta with one transformer removed. The *T*-connection is shown at *c*, in Fig. 2.

Polyphase transformers may be built for either two-phase or three-phase, but only the three-phase type has been extensively manufactured. This consists essentially of three sets of primary and secondary coils mounted upon a common magnetic circuit. Theoretically, there is considerable economy in this form of construction, both in the amount of material and in the floor space required, but practically, the saving is quite small, and on account of reduced flexibility, as well as increased cost of repairs, the three-phase transformer has not been generally adopted in America.

In less than ten years' time the design of the high-voltage transformer has passed through the experimental stage to a firm engineering basis, and while much has yet to be learned, especially regarding extremely high-voltage work, designing methods have so far progressed that results can be predicted with as great, or greater, accuracy than is possible even in the design of steam engines.

The growth in the volume of the transformer business has necessitated greatly increased manufacturing facilities, while the increased size and voltage of individual units have demanded better materials of construction and improved methods of handling apparatus during manufacture. The manufacturer has kept up, however, with commercial demands, and stands prepared to construct



ONE OF THE SUB-STATIONS AT BUFFALO OF THE CATARACT POWER & CONDUIT COMPANY, 4000. H P. TWELVE 250-KW AIR-BLAST STEP-DOWN TRANSFORMERS, MADE BY THE GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y.

SEVEN 1875-KW WATER-COOLED STEP-UP TRANSFORMERS,—2200 TO 22,000 VOLTS,—USED BY THE NIAGARA FALLS POWER COMPANY FOR ITS INTERMEDIATE-DISTANCE TRANSMISSION SYSTEM. MADE BY THE WESTINGHOUSE ELECTRIC & MFG. CO., PITTSBURG

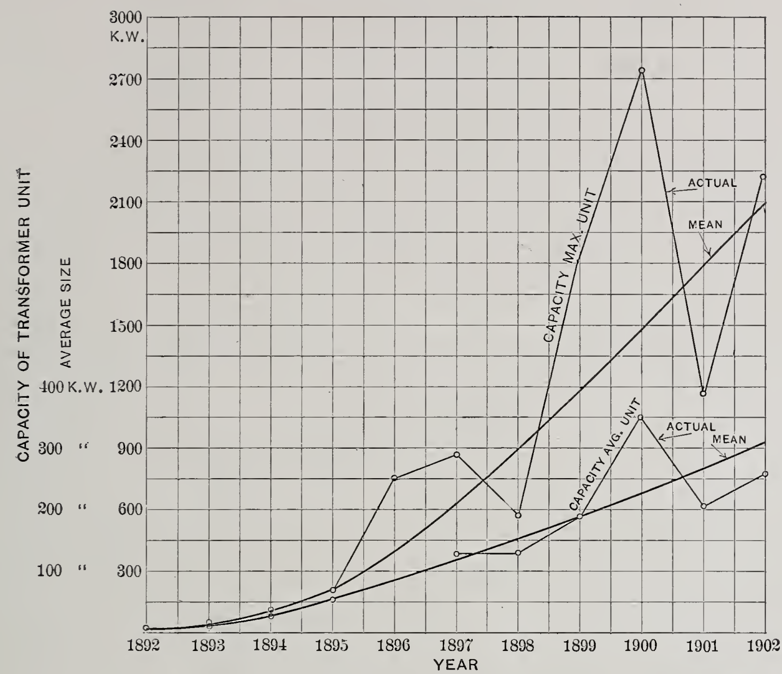


FIG. 5.—CURVES SHOWING MAXIMUM AND AVERAGE CAPACITY OF TRANSFORMER UNITS FOR DIFFERENT YEARS

transformers of any size and for any voltage which commercial conditions may require.

In considering the increase in size in voltage and in volume of business, questions which naturally suggest themselves are:—

How long will the volume of business continue to increase at its present rate? What will be the maximum size and the highest voltage for which transformers will be wound?

Definite answers to these questions are impossible, but the progress of the past may serve to indicate in a general way what may be expected in the future, and to obtain a record of past progress the curves, as given on this page and pages 149 and 151, have been plotted. These curves are made up from the data given in the table on page 137, and probably represent quite closely the whole field of high-voltage transformer work.

The curve in Fig. 2, showing the output of high-voltage transformers from 1892 to 1902, inclusive, indicates clearly the effect, upon the transmission business, of the successful outcome of the Pomona and Niagara plants, and of the introduction of the alternating-current motor and rotary converter.

The length of time that this curve will continue at its present angle depends upon the commercial condition of the whole country, and upon developments which may be made in new apparatus or in new applications of old apparatus. At the present time the indications are that for 1903 the rate of increase will be approximately the same as it has been during the last few years.

Fig. 4 shows the rapid increase in maximum voltage of the individual unit, as well as the steady increase in the average voltage of all transformers. As there has been a fairly uniform increase in maximum transformer voltage for ten years past, it seems reasonable to expect that this increase will continue for some time to come, and in the course of a few years voltages of 80,000 or even higher may be expected. A knowledge of projected work bears out this inference.

The curve in Fig. 4, showing the

average voltage of all transformers manufactured, seems to be growing flat at a little over 15,000 volts. This is due to the great number of transformers used in large cities where power is distributed over wide territories from a central station at voltages ranging from 6000 to 13,000. Unless some new conditions arise, such, for example, as long-distance railway work which will require enormous transformer capacities at very high voltages, it does not seem probable that there will be any immediate increase in the average transformer voltage.

The curves in Fig. 5 show the maximum size of transformer for each year, and also the average size of transformer unit. The curve indicating the maximum size shows a wide fluctuation from year to year. The general tendency is, however, upward, and it is expected that with the constantly increasing size of generating units and power plants the demand will be for larger and larger transformer units.

The use of transformer units of far larger size than any yet manufactured is even now under consideration, but what the maximum size will be it is impossible even to predict.

The curve showing the average size of unit is a more uniform one than that indicating the maximum size, and is rising gradually. There seems no reason to expect that constant conditions have been reached in this respect, but rather that the increase of the past will continue for some time at approximately its present rate.

In conclusion, it may be stated that while the past ten years have seen wonderful developments in high-voltage transformer construction, with a great increase in the maximum and average size and voltage of the individual unit, limits have nowhere been reached, so that in future improvements in methods of construction as well as units of larger size and higher voltage may be confidently expected.

ELECTRIC POWER IN MANUFACTURING PLANTS

By Dugald C. and William B. Jackson

THE problem of determining the most economical and satisfactory means for distributing and applying power in manufacturing establishments comprises so many elements that its solution cannot be generalised. The question assumes large proportions even when limited to the consideration of the various adaptable arrangements of electrical " drives " and their relative suitability for different classes of manufacture.

The fierce competition of to-day brings into high light the importance of a thorough grasp of all of the details in manufacturing which may improve the quality and reduce the cost of the output, and we are in a period notable for the systematic study of these details which go so far toward making successful manufacturing. The situation justifies a careful analysis of power distribution in factories, and especially of the now popular power distribution by electrical means; for the method employed for delivering the power to the machinery is one of no little importance in any large manufacturing establishment, and it is of extreme importance in some.

The great number of points at which the character of the power distribution system may affect the factory pocketbook is remarkable. In addition to determining the mere cost of delivering power to the productive machinery, the character of the power system largely affects or even controls some of the most important factors in the administration of a manufacturing plant. The reliability of the service, and the extent to which an interruption or injury at any individual part may affect the net returns of the establishment, are wholly dependent upon the power system.

The satisfactory handling of raw and finished material at the productive machines and delivering it to and from the machines are intimately dependent on the character of the power medium, as is also the quantity of finished product which may be turned out by the machines, and, to a lesser degree, perhaps, the quality of the product.

Structural conditions which determine the cost of buildings, the possibilities for perfect illumination of the workrooms, ventilation and cleanliness, and the safety of the operatives are all dependent to a large degree upon the power system which is installed.

The possibilities for natural expansion of the plant, without undue reorganisation in the departments and rearranging of the factory space, may be made or marred by the power system installed.

The most suitable location of productive machinery within the most economical area, and the extent to which portable tools may be profitably used, are features largely controlled by the characteristics of the power system.

The relative importance of these various features is materially different in the various classes of manufacturing, and this may readily account for the marked differences of opinion which are expressed when choice is to be made of the most suitable (that is, the least imperfect) system of distributing power for manufacturing purposes.

The electrical distribution of power so well fulfills the requirements that are usual to manufacturing establishments,

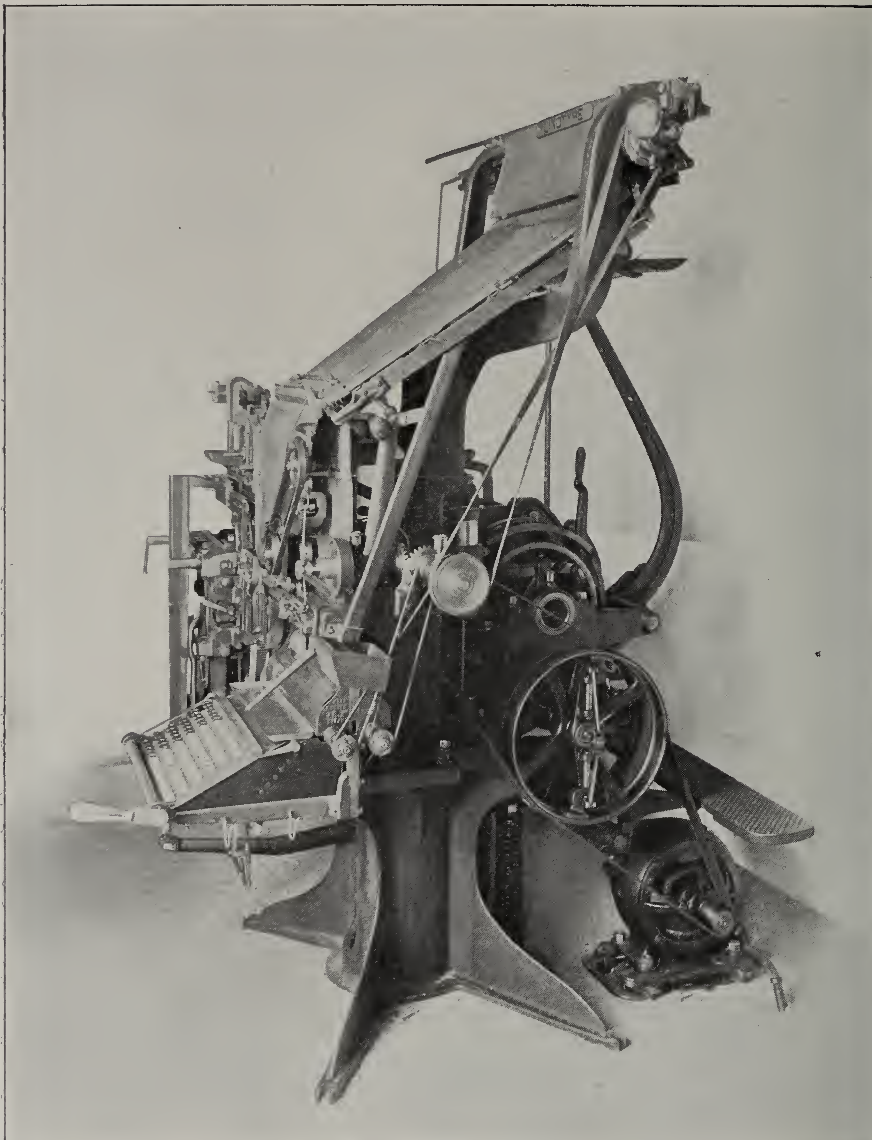


FIG. I.—A LINOTYPE MACHINE DRIVEN BY A CONSTANT-SPEED MOTOR MADE BY THE NORTHERN ELECTRICAL MFG. CO., MADISON, WIS , U. S. A.

and also lends itself so readily to unusual or special conditions, that it has come to be recognised as pre-eminent for use in the larger establishments and even for many of the smaller ones. Manufacturing requirements demand the earning of dividends, and this, in turn, requires that product shall be turned out at the least total cost, including every item rightfully chargeable to manufacturing expense.

In making a choice between the various means for power distribution a manufacturer should bear in mind the effect that the various arrangements may have on the several elements that enter into

the aggregate shop cost. The first cost of the power generating and distributing system is often of minor importance compared with other factors. This is true also of the mechanical efficiency of the power equipment, since the desired ultimate result is the production of the greatest net financial return from the money invested in the entire establishment.

The coal pile usually represents only a small fraction of the manufacturing expense. As the mechanical efficiency directly affects this, the advantages of different available systems should be given some consideration from this point of view, but this is really a minor matter. The efficiency of the distributing system and translating devices also influences the size required in the prime generating plant. These points, however, cannot be properly considered individually, but only as elements in the aggregate whole which constitutes manufacturing cost.

So many factors are comprised in the problem of most successfully driving machinery in manufactories that it is impossible to generalise; each plant requires individual analytical treatment. In such manufactories as cotton mills, thread mills, and paper mills, as a rule, constant-speed motor equipments may ordinarily predominate, since precise uniformity of speed is needed in most of the processes and any changes in the speed of the machines which may be desirable are only of periodic occurrence and can be economically provided for by means of mechanical devices or their equivalents. In machine shops, on the other hand, machinery is largely employed which demands easy speed changes and exact speed control for the highest utility.

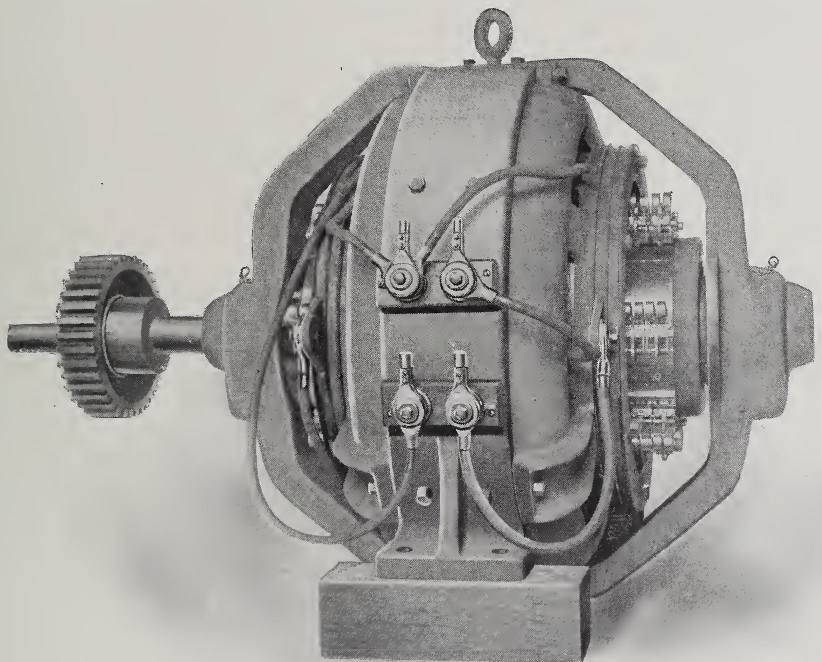


FIG. 2.—A DOUBLE-COMMUTATOR MOTOR MADE BY THE C. & C. ELECTRIC CO., NEW YORK

The flexibility pertaining to the electrical transmission, distribution, and translation of power, together with other advantages that will be touched upon later, make the electric current a favourite vehicle for use in all large manufacturing establishments. Indeed, the

electric drive has been so well received that it is now installed even in establishments, like such textile mills as require only a constant speed, where it can give little advantage as compared with the old rope and belt drives, except in the possibilities for cleanliness and convenience which it affords.

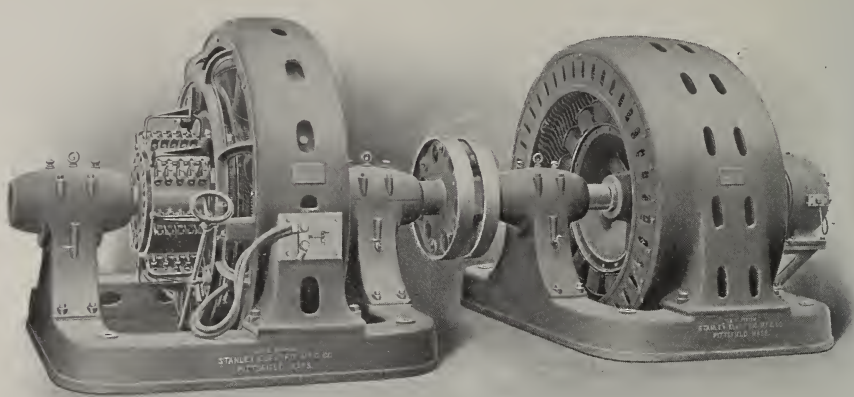


FIG. 3.—A MOTOR-GENERATOR SET WITH SYNCHRONOUS MOTOR AND DIRECT-CURRENT GENERATOR, MADE BY THE STANLEY ELECTRIC MFG. CO., PITTSFIELD, MASS.

The advantages of the electric drive are especially apparent where conditions either control or suggest the location of the factory power house at a distance, whether short or long, from the centre of manufacturing; in fact, when this condition exists, there is usually little excuse for the adoption of any other means for power distribution than the electric.

When cheap electric power may be purchased from an electric transmission plant the value of the electric drive is still further accentuated, and under these conditions the character of the electric motors to be adopted and the best methods for their speed control become the questions at issue.

Power which is supplied from a long-distance electric transmission plant is almost invariably transmitted by means of polyphase alternating currents, and the comparative wisdom of distributing the power directly to alternating-current motors or of converting it so that it may be used in direct-current motors requires careful consideration. In some cases a combination is advantageous, part of the power being distributed by means of alternating currents and the remainder being converted and distributed by means of direct currents. This conversion of the polyphase currents requires the use of a motor-generator set or of a rotary converter for changing the alternating currents into direct current.

A good idea of the appearance of a motor-generator set may be obtained from Fig. 3 and of a rotary converter from Fig. 4. It is to be understood that the motor-generator set comprises two distinct machines, usually direct connected,—one a motor to receive current from the transmission lines, the other a generator to furnish current to the distribution circuits. This double construction is clearly shown in Fig. 3. The rotary converter, on the other hand, is a single machine, the armature of which, while being driven by alternating currents from the transmission line, at the same time converts the alternating currents into a direct current of equivalent power.

As a rule, it may be considered that

motor-generator sets give greater satisfaction than rotary converters for the service that is here under consideration. This is for several reasons. Variations of the alternating line pressure or voltage will not affect the direct-current pressure where synchronous motors are employed as the drivers in motor-generator sets. And this effect is unimportant when induction motors are so employed, if the variations in line pressure are not excessive.

This cannot be said of the rotary converter, for here there is a conductive electrical connection between the alternating-current circuit and the direct-current circuit, and the pressures bear fixed relations to each other. The motor-generator sets, on the other hand, make a complete electrical separation between the primary and secondary circuits. Motor-generator sets also admit of ready means for regulating the distribution pressure regardless of the transmission pressure, which cannot be said of rotary converters, and transient troubles which may affect the transmission lines are less liable to disturb the operation of the former.

In cases where the productive machinery of a manufacturing establishment is to be maintained at a constant speed, or only a limited number of fixed speeds are needed, the alternating-current induction motor is always the peer of the direct-current motor. The induction motor may be built without commutator and brushes,—the most vulnerable portion of the direct-current motor,—and in very dirty or wet places this structural difference becomes of decided importance to the reliability of service.

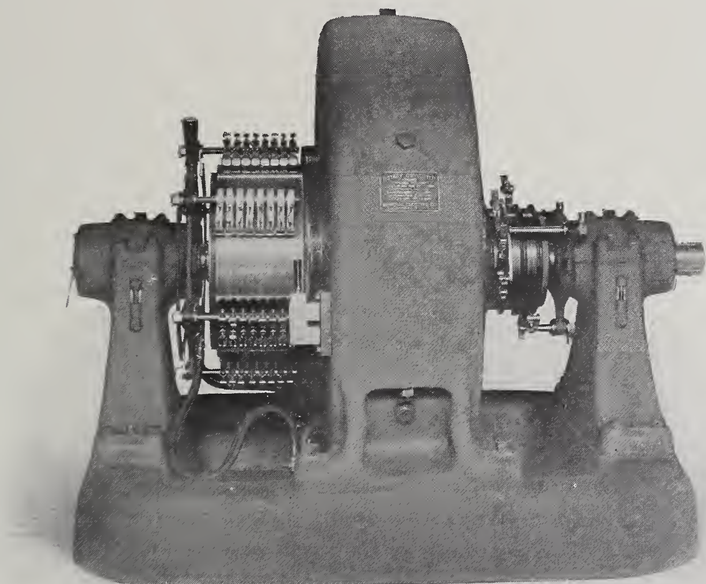


FIG 4.—A ROTARY CONVERTER MADE BY THE GENERAL ELECTRIC COMPANY OF SCHENECTADY, N. Y. THE COLLECTOR RINGS CAN BE SEEN AT ONE END OF THE ARMATURE AND THE COMMUTATOR AT THE OTHER

In factories working very inflammable materials, and where the least spark of fire is a source of apprehension on account of the risk of a conflagration, the commutatorless induction motor must

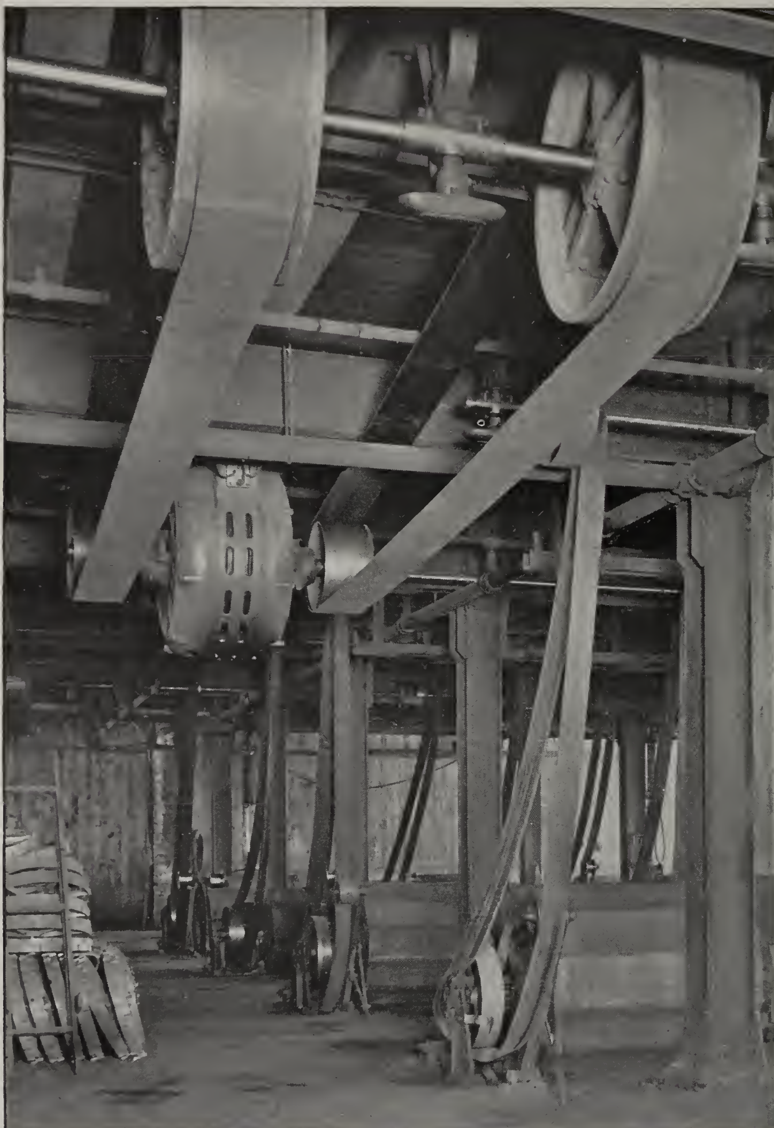


FIG. 5—AN INDUCTION MOTOR FROM THE GENERAL ELECTRIC COMPANY, OF SCHENECTADY, N. Y., DRIVING TUMBLING BARRELS IN A FOUNDRY. THE MOTOR IS HUNG FROM OVERHEAD, THUS PERMITTING IT TO BE LOCATED REGARDLESS OF PASSAGE WAYS

be considered far superior to any type of direct-current motor. The induction motors shown in Figs. 7, 8, 9 and other illustrations are devoid of any moving electrical contacts. Motors of this type contain what are commonly called "squirrel cage" armatures, the name being derived from the arrangement of the armature conductors in semblance of the rotary cylinder of a squirrel cage. Their simplicity of construction and reliability of operation are remarkable.

Fig. 7 illustrates an induction motor in which the armature winding consists

of wire coils so arranged that extra resistances may be inserted into the armature circuits when the motor is started or when it is desired to vary the speed of the armature. This resistance is constructively related to the armature, and may be controlled by means of the button which may be seen at the left hand end of the armature shaft in the illustration. The substantial construction, from which such motors derive great reliability in service, will be appreciated by examining the illustrations.

Owing to the inherent characteristics of induction motors, they are not well adapted for duties where variable speeds are needed, since they cannot be operated at speeds other than that dictated by the number of poles in the magnetic field and the frequency of the supply current, except at the sacrifice of regulation.

Single - phase, alternating - current, series and repulsion motors, which are now coming into particular prominence, present possibilities in the direction of speed control which may ultimately enable them to rival or even surpass direct-current motors for this service.

At the present time where variable-

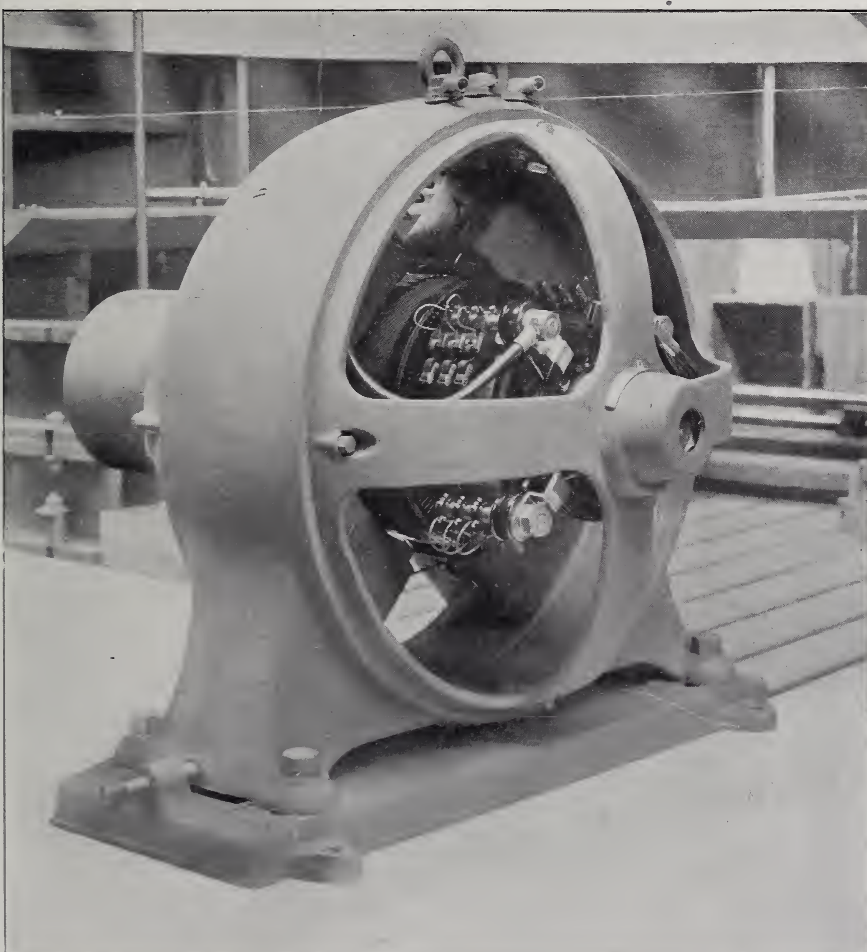


FIG. 6—A CONSTANT-SPEED, DIRECT-CURRENT MOTOR MADE BY THE NATIONAL ELECTRIC CO., MILWAUKEE, WIS., ARRANGED FOR BELT CONNECTION

speed service is required the direct-current motor has been commercially developed with unrivalled success. The general appearance of direct-current motors is fairly illustrated in Fig. 6, though it should be remembered that the various manufacturers of motors all adhere to their several individual designs.

Every machine, whether in the machine shop, the factory or elsewhere, ought to be run at its most economical speed under each separate condition of its service. Some one speed is most economical for one class of service, and other speeds for other classes of service; that is, there are special speeds pertaining to each class of work at which the greatest quantity of satisfactory product can be turned out at the least total cost. With increasing keenness in competition, the importance of operating each machine always at its best speed becomes increasingly apparent.

In driving metal-working machinery, the most economical results may usually be obtained when the machines are driven to remove a certain maximum weight of metal per hour. This maximum, of course, differs with the metal worked, the character of the article to be produced, and the particular process under way; but in heavy work it is substantially independent of the size of the piece which is being machined. In other words, machine tools may advantageously be held to the limit of reasonable endurance where the character of the work will permit.

This requires that the cutting speed at which the tool acts upon the piece shall be fixed, in lathes and like machinery, by the conditions of work and not by the size of the piece; that the motor shall deliver equal power, regardless of its rotating speed, the latter being determined by the diameter of the rotating piece; that the torque at the chuck or face-plate must increase with decreasing speed, in other words, the torque exerted on the main spindle must be in inverse ratio to its rotating speed; and that the speed for each setting of the speed-controlling mechanism shall hold practically constant, regardless of variations in the power absorbed, up to the greatest power of the motor.

For such a situation, the ideal condition for an electric motor is one in which the motor may always operate at a constant speed, all variations in the speed of the machines being accomplished through some extraneous device, such as a mechanical speed-varying device. The well-known mechanical limitations of such arrangements are partially overbalanced by disadvantages of added ex-

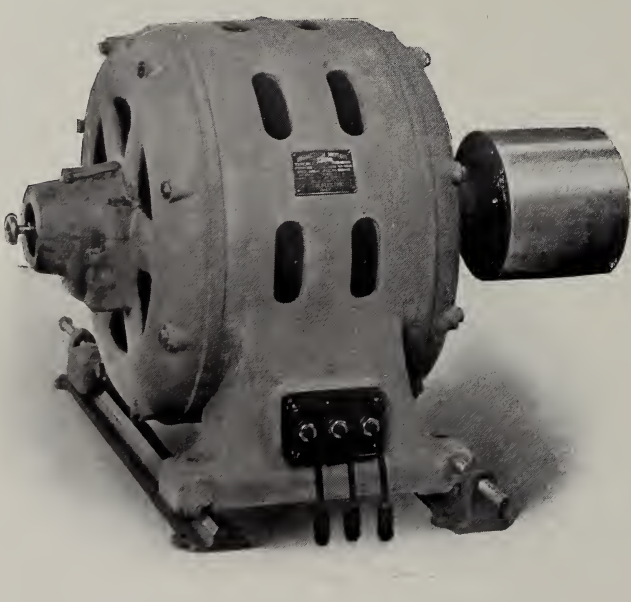


FIG. 7.—AN INDUCTION MOTOR MADE BY THE GENERAL ELECTRIC CO., SCHENECTADY, N. Y. THE TERMINALS FOR CONNECTION TO THE DISTRIBUTION CIRCUITS ARE HERE SHOWN AT THE FRONT, AND ALSO A KNOB AT THE END OF THE SHAFT TO CONTROL THE STARTING RESISTANCE

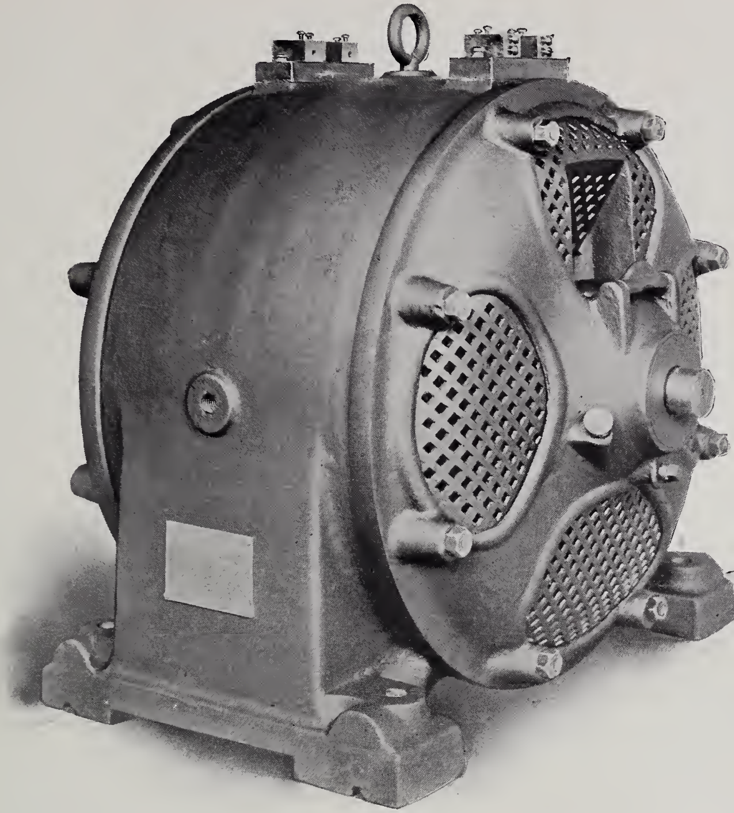


FIG. 8.—A TWO-PHASE INDUCTION MOTOR WITH SQUIRREL-CAGE ARMATURE, MADE BY THE WESTINGHOUSE ELECTRIC & MANUFACTURING CO., PITTSBURGH. THE REVOLVING ELEMENT IS SIMPLE AND REMARKABLY ROBUST IN CHARACTER. THE BINDING POSTS FOR RECEIVING THE LINE WIRES ARE SHOWN ON THE TOP OF THE MOTOR

pense occasioned by the employment of special variable-speed electrical motors.

As already pointed out, a variable-speed arrangement which may be counted satisfactory for service in most manufacturing operations must hold closely to the desired fixed speed at each setting of the controller, whether the machines run with or without load.

When cogent reasons dictate the adoption of alternating current for power distribution in a factory, even if variation of speed is desirable for a few machines, a combination of pulleys, gears or clutches may be arranged to effect the speed changes that may be required for such machines. Magnetic clutches, of which a few are in use, offer attractive features in connection with this service and bid fair to enter largely into practice in driving variable-speed machinery.

A satisfactory variation in speed cannot be accomplished by the introduction of resistance into the circuit of a motor armature, either with direct-current or alternating-current motors. Such use of resistance does affect the speed, but it introduces a condition which prevents the constancy of speed under varying load,—which is an undesirable condition in almost all cases of shop or factory drives.

This consideration, however, does not ordinarily bear on crane, hoist or tramway work, and speed control of

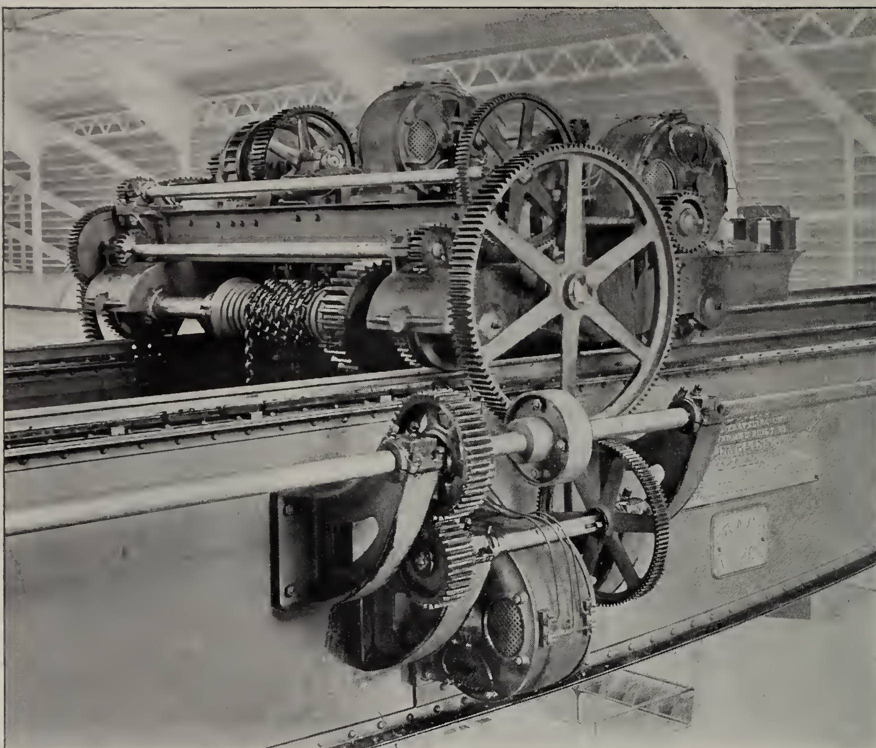


FIG. 9.—WESTINGHOUSE INDUCTION MOTORS OPERATING A TRAVELLING CRANE

motors in such service by the so-called rheostatic control is very common. Fig. 9 illustrates a travelling crane equipped with alternating-current motors.

A small variation in the speed of any direct-current, shunt-wound motor can be produced by varying the strength of the magnetic field, when the electrical pressure at the armature terminals is maintained at a constant value. This results in serious sparking at the brushes and other disadvantages if carried far with the ordinary standard motors; but special motors are now designed and built so as to be adapted for the purpose, and these give remarkably satisfactory results wherever the range of required speed variation is not too great.

Where field regulation alone is used to accomplish speed variation, the power plant equipment and distributing circuits are not different from those required for running any direct-current, constant-speed motor equipment, and the power system is one of extreme simplicity.

Variation in the field strength is accomplished in two ways,—either by varying the amount of current passing through the field windings by means of a variable rheostat inserted in the branch containing the field windings of the motor and thus changing the field strength, or by varying the reluctance of the magnetic circuit and thereby varying the strength of the magnetic field by acting directly on the iron path for the magnetism.

In Figs. 11 and 12 different views are shown of an electric motor designed for speed variation through change of field current, and Fig. 13 illustrates a motor designed for speed variation through change in the reluctance of the magnetic circuit. A variable resistance, usually called a rheostat, is placed in circuit with the field windings of the former type of motor, by which the magnetising

current flowing through these windings may be increased or diminished at the will of the operator, thereby increasing or diminishing the field strength. In the case of the latter type of motor, the magnetic circuit is so arranged that portions of it may be moved relatively to each other, by which the reluctance of the iron path to the establishment of the magnetism may be changed, thus providing a means whereby the field strength may be increased or diminished over a certain range at the will of the operator.

The amount of satisfactory control that can be had through the variation of the field strength is circumscribed in range, however, though the limits of such control are being continually widened.

Certain other methods for the speed control of direct-current motors are briefly described below that depend for their value upon a principle which may be so expanded as to give any range of control desired, though such a result is not obtained wthout introducing some disadvantages, such as added complication in the system and greater first cost.

The speed of a shunt-wound motor increases and diminishes with the electric pressure across its armature terminals when its field magnetism remains constant. To take advantage of this inherent characteristic of shunt-wound motors, two or more supply circuits are run to each motor; from these different voltages may be applied to the motor armature as desired, the pressure across the field circuit being retained at a fixed value. Such an arrangement, when kept within reasonable limits, in com-

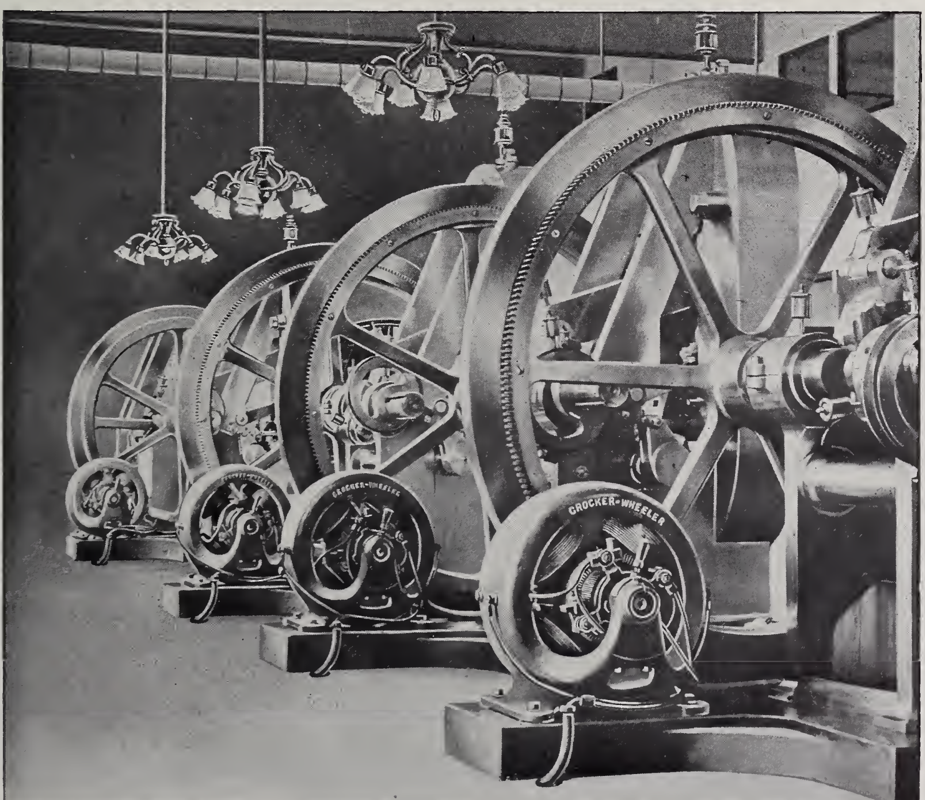


FIG. 10.—STAMPING PRESSES IN THE UNITED STATES MINT AT PHILADELPHIA DRIVEN THROUGH GEAR CONNECTION BY INDIVIDUAL CONSTANT-SPEED CROCKER-WHEELER MOTORS

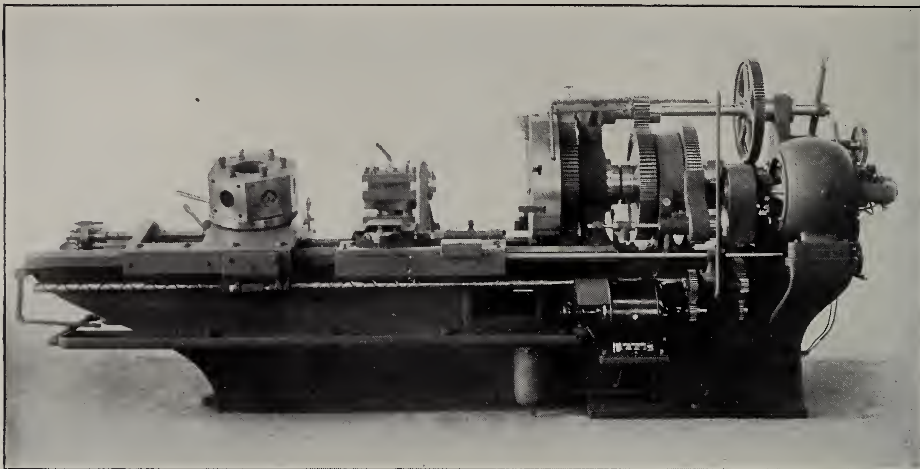


FIG. 11.—A DIRECT-CURRENT VARIABLE-SPEED MOTOR, MADE BY THE NORTHERN ELECTRICAL MFG. CO., OF MADISON, WIS., DRIVING A TURRET LATHE MADE BY THE GISHOLT MACHINE COMPANY OF THE SAME PLACE

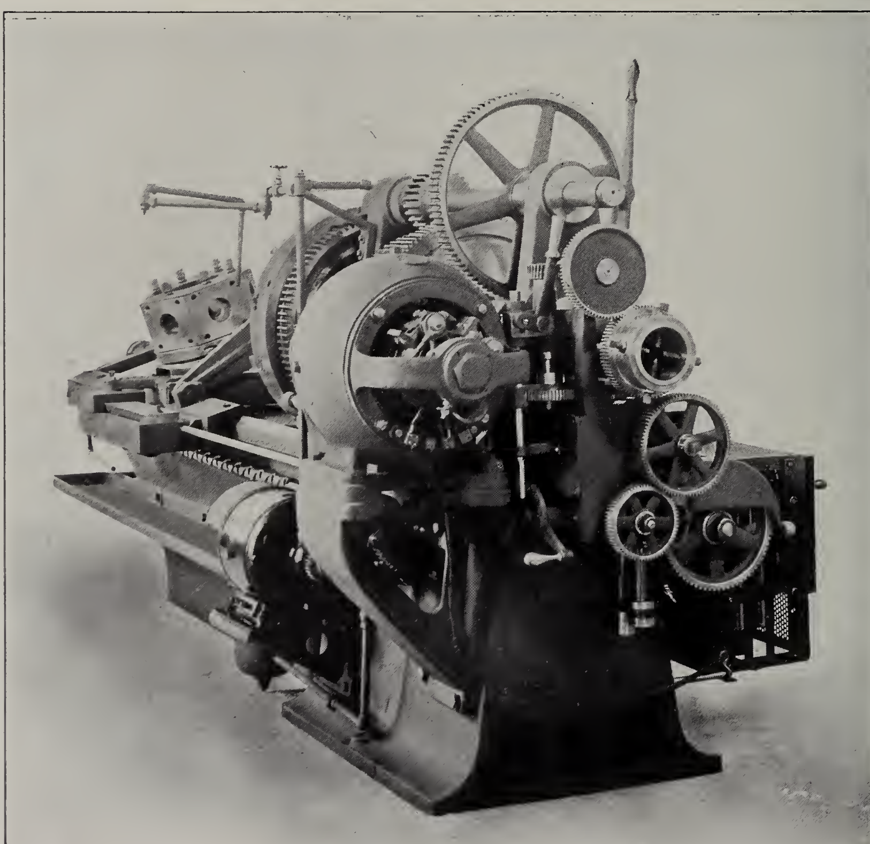


FIG. 12.—A REAR VIEW OF THE "GISHOLT" LATHE AND "NORTHERN" MOTOR SHOWN ABOVE

bination with field control, permits of a wide and finely graded speed variation without involving excessive mechanical and electrical complexity.

Probably the simplest application of this principle includes the employment of the ordinary three-wire system such as is commonly used for electric lighting, in which the full pressure, which we will designate as V, exists between the outside wires, and one-half the full pressure, which we will designate as $\frac{1}{2} V$, exists between either outside wire and the middle wire. The field circuit of a motor used in this arrangement is connected permanently as a bridge between the outside wires, and the armature connections are so arranged that the armature may be connected as a bridge either between the outside wires or between one outside wire and the middle wire, thus obtaining two speeds for the motor, one of which is one-half as great as the other, without any change in the field excitation. Intermediate variations in speed may be produced by variation in the field strength, according to the methods already described.

A diagrammatic sketch of this arrangement is given in Fig. 15. The usual starting rheostat which accompanies an electric motor and its automatic releasing device are omitted from the diagram for the sake of clearness. The variable field rheostat and the switch for transferring the armature connections from one pair of wires to another (from $\frac{1}{2} V$ to V), and *vice versa*, are illustrated as separate switches, though they are preferably incorporated in one joint controller so that they may be manipulated by a single controller handle. The first position of the controller handle brings the motor armature across $\frac{1}{2} V$ (the lower pressure) with all resistance cut out of the field circuit. This causes the

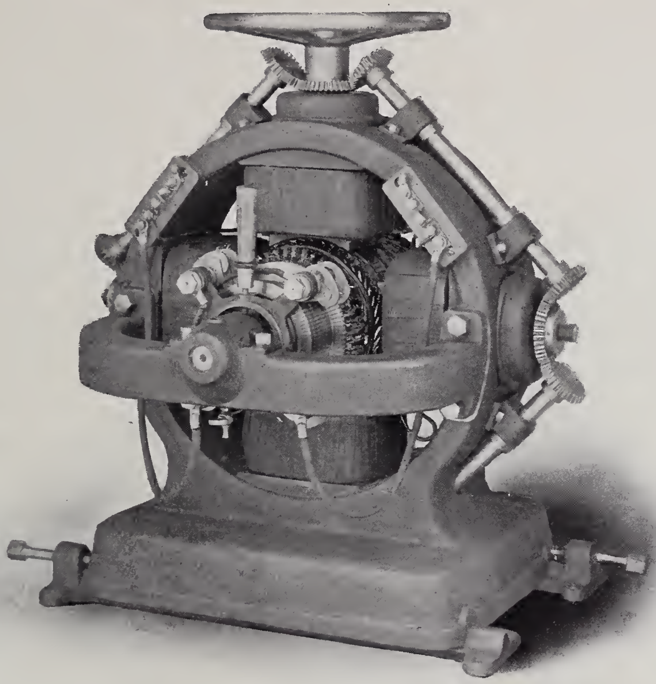


FIG. 13.—A MULTI-SPEED MOTOR MADE BY THE STOW MFG. CO., OF BINGHAMTON, N. Y. THE HAND WHEEL, SHAFTS, AND BEVEL GEARS SHOWN, SERVE IN MAKING THE INTERNAL SPEED-VARYING CHANGES

motor to run at the slowest speed. Then step by step the resistance is introduced into the field circuit until it is all in circuit, the speed of the motor being increased with each step.

A succeeding step on the controller removes all of the resistance from the field circuit and simultaneously throws the armature across V (the highest pressure), corresponding to the higher speed. Then the resistance is again introduced into the field circuit step by step, and the highest speed of the motor is reached at the last step. Sometimes a buffer resistance is introduced into the armature circuit at the instant the change is made from the lower to the higher pressure, to prevent a possible excessive rush of current through the armature at that instant.

The motor which is used with such an arrangement of circuits and motor connections must be of a special design, arranged to permit satisfactory commutation under considerable changes in field strength, or the speed changes will be too abrupt and the available running speeds too few in number. The extent of the field control must be sufficient to increase the motor speed from the lowest speed when the armature is connected to the lower voltage to the lowest speed when the armature is connected to the higher voltage. As the higher pressure is just double the lower pressure, the speed change produced by the change of the magnetic field must, therefore, be approximately from 1 to 2.

This method of speed control is extended materially further in some equipments by increasing the number of circuit wires leading to the motors. One other plan which has been employed involves the use of four circuit wires, between which the maximum pressure is divided so that six different pressures are available for running the motor. The connections to the field are continuously maintained as a bridge across one of the circuits. Such an arrangement gives what may be designated as six normal motor speeds,—that is, six different speeds without change in field excitation. Intermediate speeds may be produced by varying the strength of

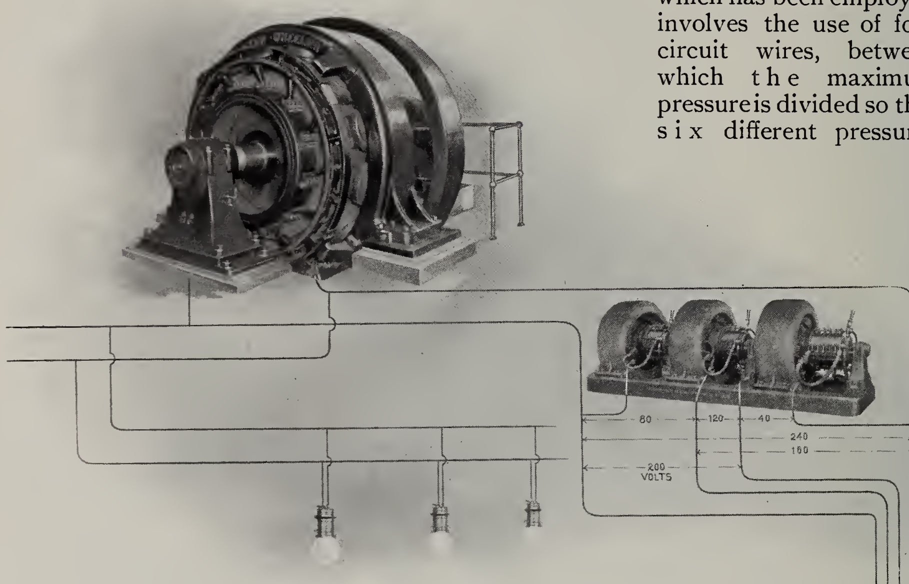


FIG. 14.—REPRESENTATION OF A MULTIPLE-VOLTAGE SYSTEM AS APPLIED BY THE CROCKER-WHEELER COMPANY, OF AMPÈRE, N. J. THE SAME GENERATOR IS SHOWN AS FURNISHING ELECTRIC CURRENT FOR BOTH LIGHTING AND POWER

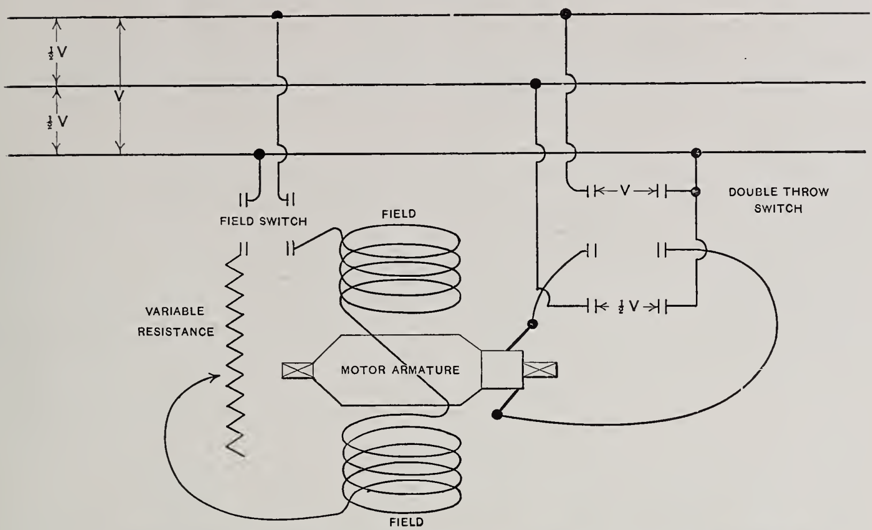


FIG. 15.—DIAGRAMMATIC REPRESENTATION OF THE THREE-WIRE, VARIABLE-SPEED MOTOR CONTROL SYSTEM

the magnetic field of the motor or by introducing resistance into the armature circuit. The latter is not a satisfactory means, however, since the speed is caused to vary with the load, as already explained.

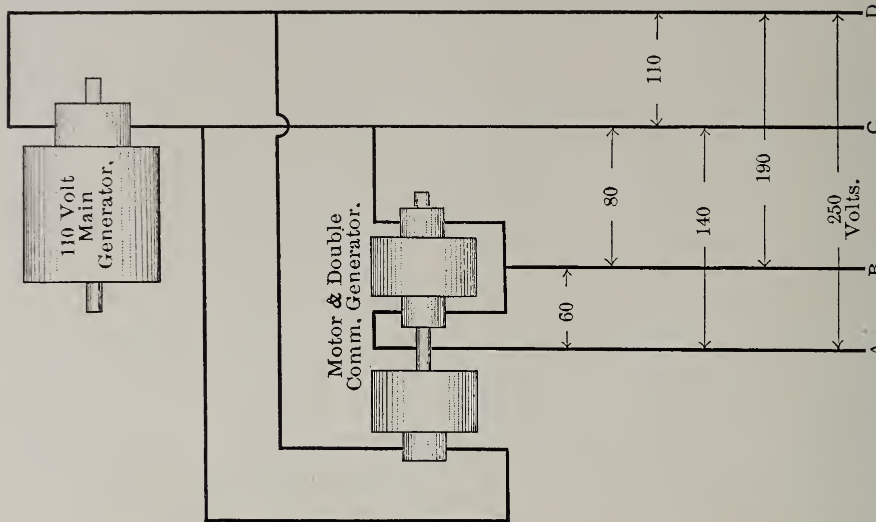
The arrangement here referred to is quite generally called the "multiple voltage" system as distinguished from the "three-wire" system, and the general scheme of connections is illustrated in Figs. 14 and 16. Fig. 14 represents one arrangement of circuits which has been applied in commercial service for multiple-voltage control. The pressures here increase by equal steps or in arithmetical progression. This arrangement is not well adapted for intermediate speed variations, owing to the different percentages of speed change which are produced by the voltage steps.

This arrangement of circuits requires either three separate generators or a main generator with certain auxiliary machinery that is used to divide the main pressure between the several circuits or to supply them with the additional voltages. The auxiliary machinery is ordinarily called a "balancer" or a motor-generator set, depending upon the manner of its association with the main generator.

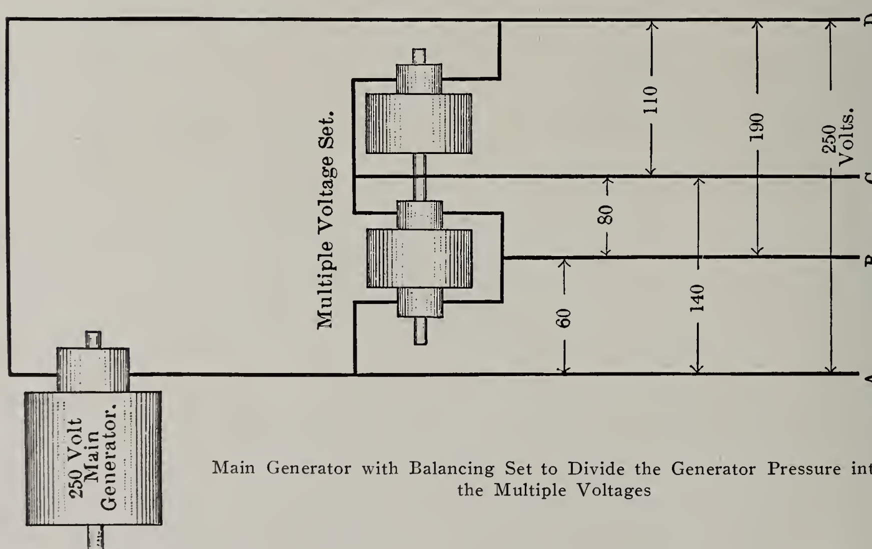
Fig. 20 illustrates a "balancer" constructed by the Crocker-Wheeler Company. This comprises in effect three direct-current, combination motor generators upon a single shaft. The summation of the pressures of these machines is equal to that of the supply circuit, and the individual pressures and combinations thereof give the multiple voltage pressures. The "balancer" machines, therefore, divide the pressure of the main generator, as it were, between the distribution circuits.

Fig. 16 represents an arrangement of circuits in which the steps by which the pressures increase are of approximately equal percentages or in geometrical progression. This arrangement is well adapted for intermediate speed control by field variation, since closely equal percentage increments of speed, caused by weakening the magnetic field, carry the motor speed from that resulting with normal field strength at any one armature pressure to that resulting with normal field strength at the next higher pressure. This results in an arrangement by which a desirably uniform control of the speed may be produced through the maximum range.

Fig. 17 illustrates a "balancer" constructed by the Bullock Electric Manu-



Main Generator with Auxiliary Booster to Furnish the Multiple Voltages



Main Generator with Balancing Set to Divide the Generator Pressure into the Multiple Voltages

FIG. 16.—DIAGRAMMATIC REPRESENTATION OF A MULTIPLE-VOLTAGE SYSTEM AS APPLIED BY THE BULLOCK ELECTRIC MFG. CO.

facturing Company for use upon a three-wire, multiple-voltage system. The four-wire "balancer" is exactly similar to this, only three machines are mounted upon one base instead of two.

One of the arrangements of the apparatus and circuits which are illustrated in Fig. 16 represents the production of the multiple voltage by splitting the pressure of the main generator, as it were, and appropriately dividing it between the distributing circuits by means of the "balancer." The pressure of the main generator in this case is equal to the highest circuit pressure. The other arrangement illustrated represents the production of the multiple voltages by means of a motor generator. In this case the generator pressure is equal to one of the lower circuit pressures.

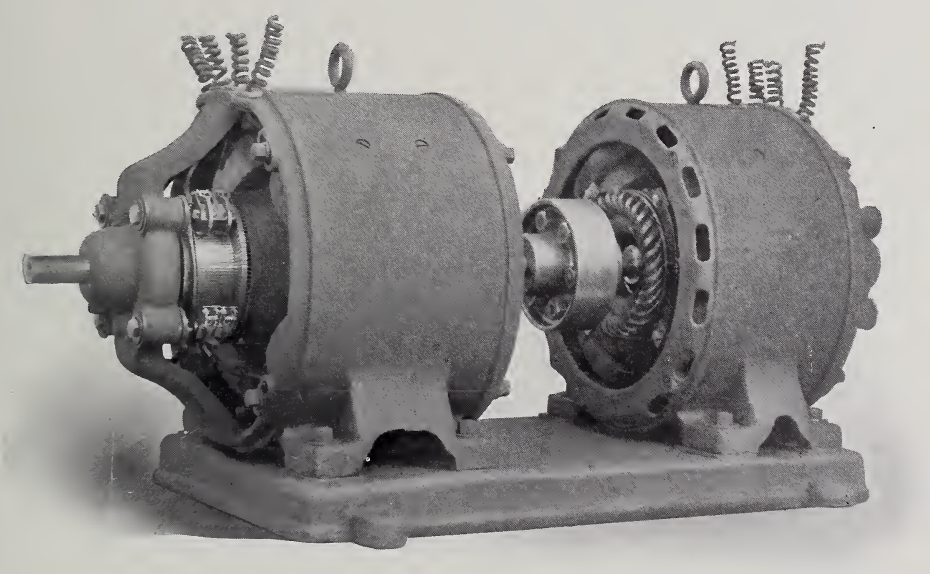


FIG. 17.—BALANCING SET AS USED BY THE BULLOCK ELECTRIC MFG. CO., OF CINCINNATI, O., IN THEIR THREE-WIRE MULTIPLE-VOLTAGE SYSTEM OF ELECTRIC POWER DISTRIBUTION

The capacity of the "balancer" that may be required for any plant must be determined by a consideration of the actual work to be done. It must be of sufficient capacity to carry the maximum current that may be demanded at any time by any of the circuits which it feeds. The proportion that this capacity must bear to the total generating capacity is widely different for different plants, and must be approximated for each individual case.

When the multiple-voltage system is employed without intermediate control by field variation, standard constant-speed motors may be used in connection with the circuits to drive the productive machinery, but the speed changes that can be made are then limited in number and differ by large jumps. Where field variation is resorted to for the purpose of extending the usefulness of the arrangement, in such a system as is illustrated in Fig. 16, for instance, the motors must be specially designed and adapted to a possible field regulation capable of giving a speed variation of approximately 40 per cent. to produce an even speed variation from the lowest speed to the highest.

The different changes in armature connections and field strength are readily accomplished in either of the methods above described by the use of controllers of drum form in connection with suitable rheostats, and the general method of changing the circuit arrange-

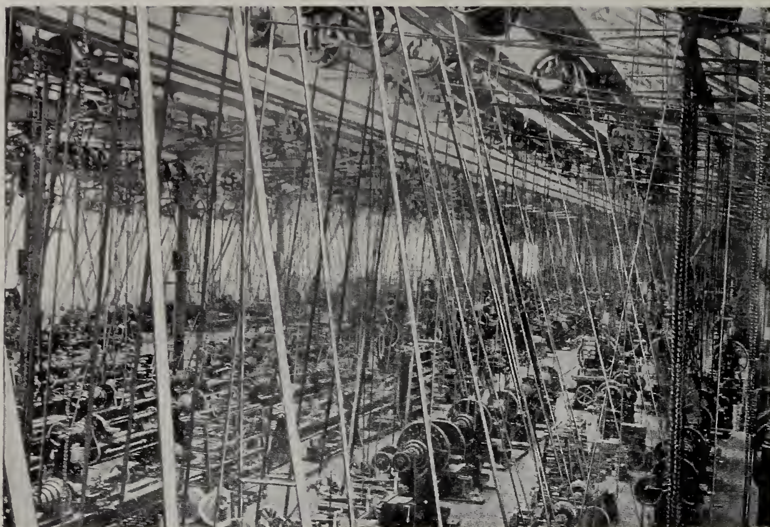


FIG. 18.—A LARGE SHOP DRIVEN BY SHAFTS AND BELTS

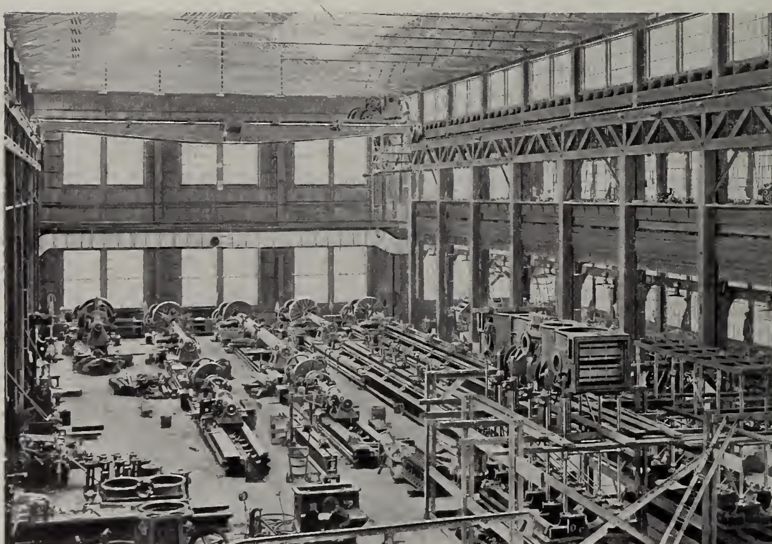


FIG. 19.—A LARGE SHOP—THAT OF THE BULLOCK ELECTRIC MFG. CO., AT CINCINNATI WITH MULTIPLE-VOLTAGE ELECTRIC-DRIVE

A CONTRAST BETWEEN BELT AND ELECTRIC TRANSMISSION

ments for modifying the motor speeds is the same as described in connection with the three-wire system. But the controllers must be arranged to make several circuit changes for the armature connections instead of one.

In Fig. 25, which illustrates a Crocker-Wheeler Company motor driving a radial drill, the controller may be plainly seen.

In another distinct method, which may be employed for varying the speeds of motors used in manufacturing establishments, the current is supplied to the armature of each motor from an individual generator, and a separate current supply of constant pressure is employed for field excitation. In this case the strength of the magnetic field of the motor may be constantly maintained at its most satisfactory value, and difficulties from sparking at the commutator of the motor may be thereby avoided.

The variation of speed of any motor is here produced by varying the pressure developed by the appropriate generator so that the pressure between the armature terminals of the motor is varied as desired. This arrangement makes it possible to produce an even variation in the speed of the motor from the standstill up to the maximum which considerations of mechanical safety will permit, provided suitable means are afforded for graduating the pressure produced by the dynamo. The practical use of this arrangement, however, must be limited to special conditions on account of the inconvenience and expense involved in providing a separate generator for each motor. The plan has been employed for operating structures like the turrets of battleships and for operating large printing presses, but it has not found any wide field of usefulness.

Another plan for electrical speed variation uses a motor having two separate windings on its armature, each connected to its individual commutator. The external connections leading to the brushes on the commutators are so arranged that the armature windings may be put in series or in parallel, as may be desired.

A promising plan for factory power distribution using variable-speed motors is one in which the armature of each motor is supplied with two separate sets of windings of different numbers of turns of wire, the two windings being connected to different commutators. The windings may be used separately or they may be connected in series acting in

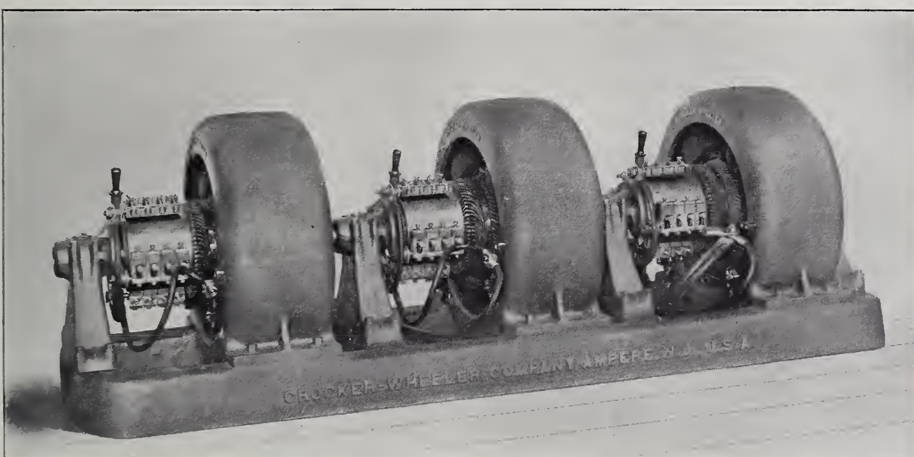


FIG. 20.—A BALANCING SET USED BY THE CROCKER-WHEELER CO. FOR SUPPLYING THE SEVERAL PRESSURES TO MULTIPLE-VOLTAGE CIRCUITS

FIG. 21.—A BAND SAW, MADE BY THE J. A. FAY & EGAN COMPANY, OF CINCINNATI, O., IN THE PATTERN SHOP OF THE NATIONAL ELECTRIC CO., OF MILWAUKEE, WIS., DRIVEN BY ONE OF THE LATTER COMPANY'S MOTORS

unison, or again they may be connected in series acting differentially or in opposition.

Assuming the armature to be proportioned so as to produce a geometrical progression in the effective armature conductors available in the four combinations, this construction, when combined with field control as used with multiple-voltage systems, affords all the advantages in speed control and regulation which might be afforded by a four-pressure multiple-voltage system. It also affords an additional advantage of no mean value, namely, that the distributing circuits of an entire shop may consist of ordinary two-wire circuits from which standard constant-speed motors and double-armature, variable-speed motors may be operated with equal satisfaction, while the multiple voltage arrangements essentially require special multiple circuits extending to each variable-speed motor.

All of the arrangements above enumerated for producing controllable motor speeds, when used in connection with work in which the power required is in direct ratio to the driving speed, would afford almost ideal means for factory power distribution were it not for the complexity which is an accompaniment of some of them.

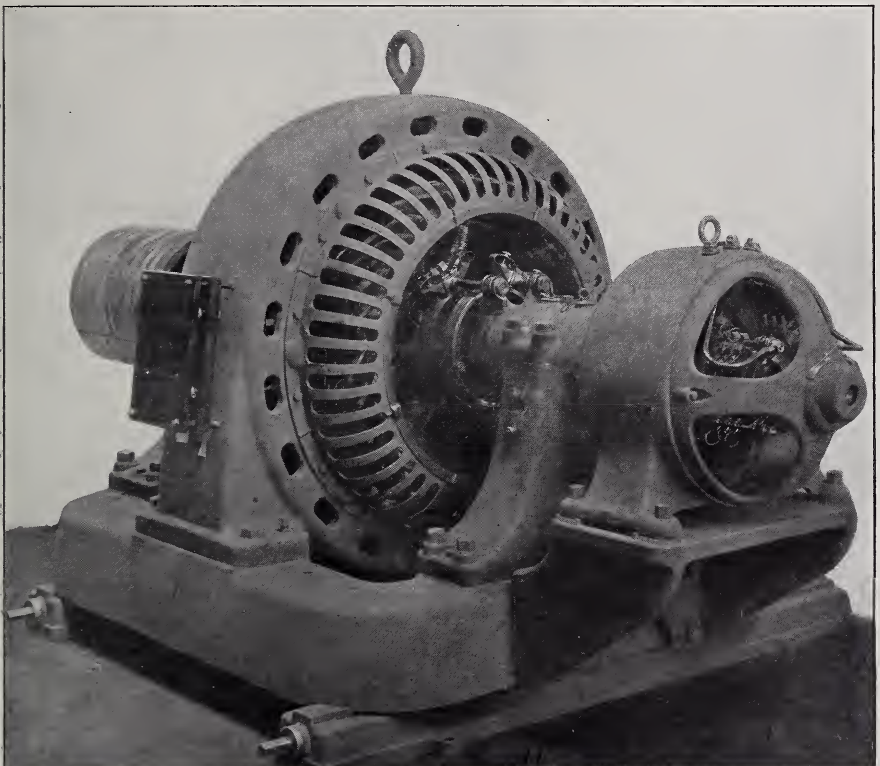


FIG. 22 —A SYNCHRONOUS MOTOR MADE BY THE NATIONAL ELECTRIC CO., OF MILWAUKEE, WITH DIRECT-CURRENT EXCITER MOUNTED ON THE MOTOR SHAFT

In case the work requires a fixed power to be delivered at different speeds determined by the immediate conditions, the speed control produced by the aforesaid methods is still very satisfactory; but the expense and complication involved in attaining the result is far from being equally satisfactory. This is due to the fact that the power of a well-

designed motor is directly proportional to the surface velocity of its armature, and the motor becomes very heavy and expensive when called upon to deliver considerable power at a very low speed (in revolutions per minute) when it must be also capable of delivering the same amount of power at a high speed without exceeding a safe surface velocity.

A motor which will deliver three horse-power when running at 200 revolutions per minute in a satisfactory manner, and which must be capable of safely delivering the same power at 1200 revolutions per minute, may be expected to be four or five times as heavy as a motor designed to deliver three horse-power when required to operate only at 1200 revolutions per minute. It is, therefore, desirable to utilise suitable mechanical speed-changing devices in connection with variable-speed motors wherever very wide ranges of speed are desired.

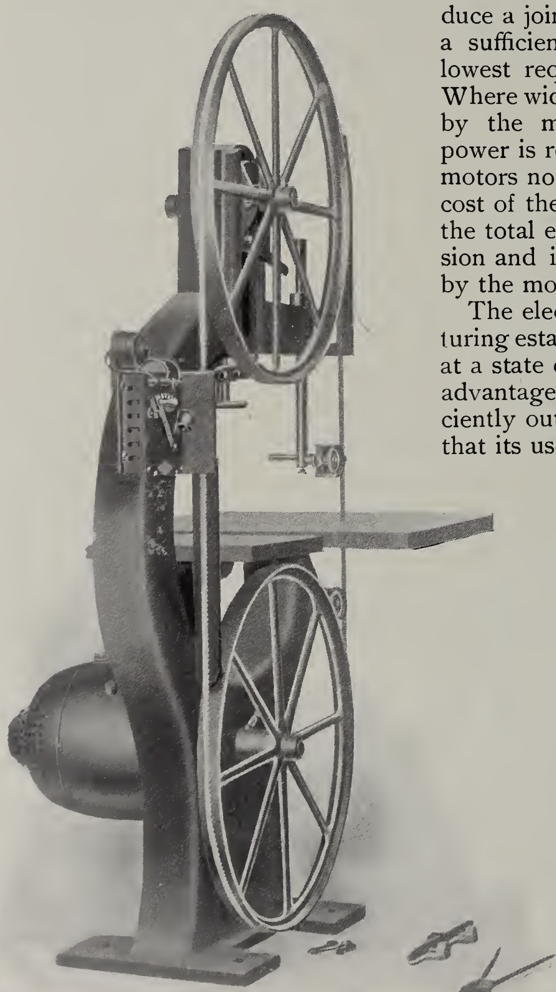


FIG. 23 —ANOTHER FAY & EGAN BAND SAW, EQUIPPED ELECTRICALLY BY THE AKRON ELECTRIC MFG. CO., AKRON, O.

The mechanical devices should be capable of producing a few changes in speed which divide the total range in geometrical progression, and the electrical system may be relied upon to economically fill up the gaps and produce a joint speed control which affords a sufficiently even variation from the lowest required speed to the highest. Where wide speed changes are produced by the motors alone (when uniform power is required) the large size of the motors not only adds materially to the cost of the equipment, but also reduces the total efficiency of the power conversion and increases the space occupied by the motors.

The electric drive for use in manufacturing establishments has not yet arrived at a state of ultimate perfection; yet its advantages, as it is now applied, sufficiently outweigh the disadvantages, so that its use in some form is now so widespread as to be almost universal. This is not surprising, for the electric system affords great flexibility in the arrangement of machinery and in extensions of the plant. It avoids the necessity for long and heavy line shafting, thus reducing friction losses and removing from the building the weight and vibration incident upon their use, and the liability of fire owing to overheated bearings. It does away with intricate and heavy belting, thus affording a well-lighted shop which is readily kept neat and clean. By doing away with belts and shafts it improves the convenience of crane service and the handling of material. It makes

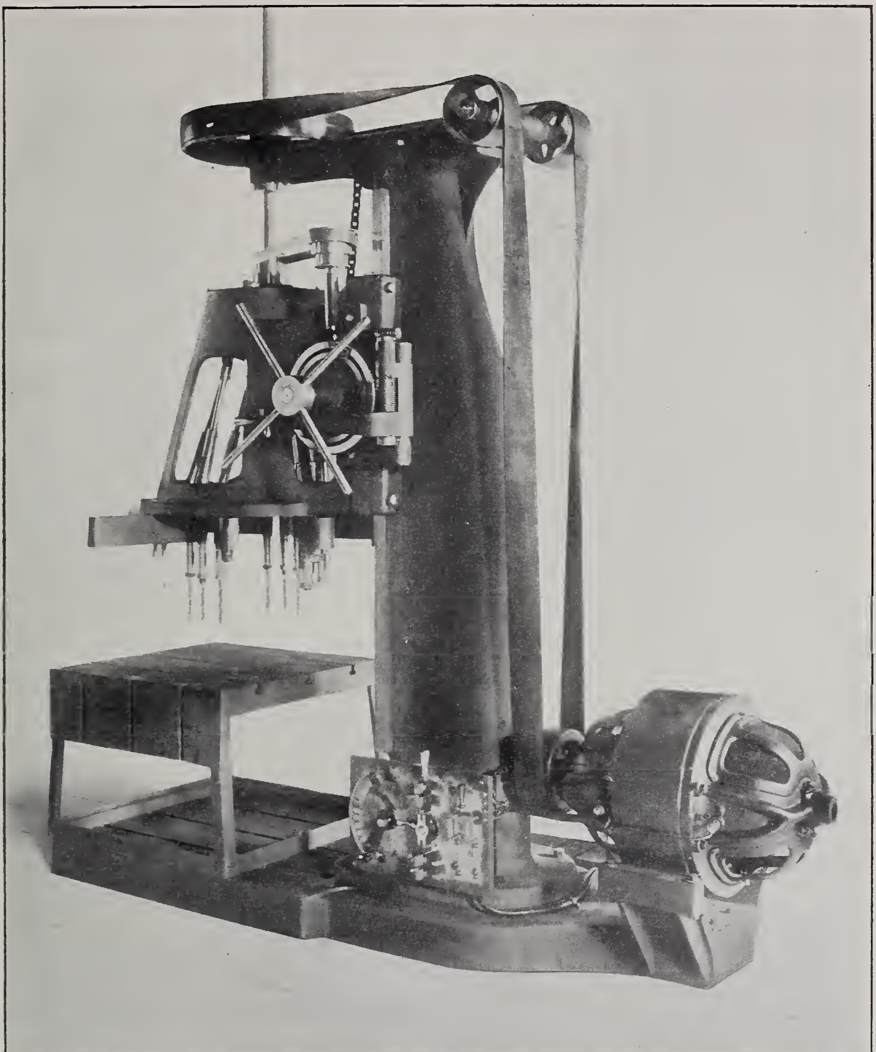


FIG. 24.—A VARIABLE-SPEED MOTOR MADE BY THE COMMERCIAL ELECTRIC COMPANY, INDIANAPOLIS, IND., DRIVING A MULTIPLE SPINDLE DRILL MADE BY THE WESTERN MACHINE CO., HOLLAND, MICH.

possible the use of any machine or group of machines alone, without long lines of idle shafting and belting. In it is found the only adequate drive for portable machines; and it furnishes the essential elements of satisfactory speed variations wherever these are needed.

Figs. 18 and 19 illustrate the contrast between the appearance of a belt-driven shop and one in which the machines are equipped with individual motors. The relative advantages for most manufacturing plants of the electric drive properly installed, compared with the belt drive, are as deeply contrasted as the external appearances illustrated in Figs. 18 and 19.

In cases where alternating-current motors are employed, induction motors are now used almost exclusively for all situations where the translation of small amounts of power is desired; but where

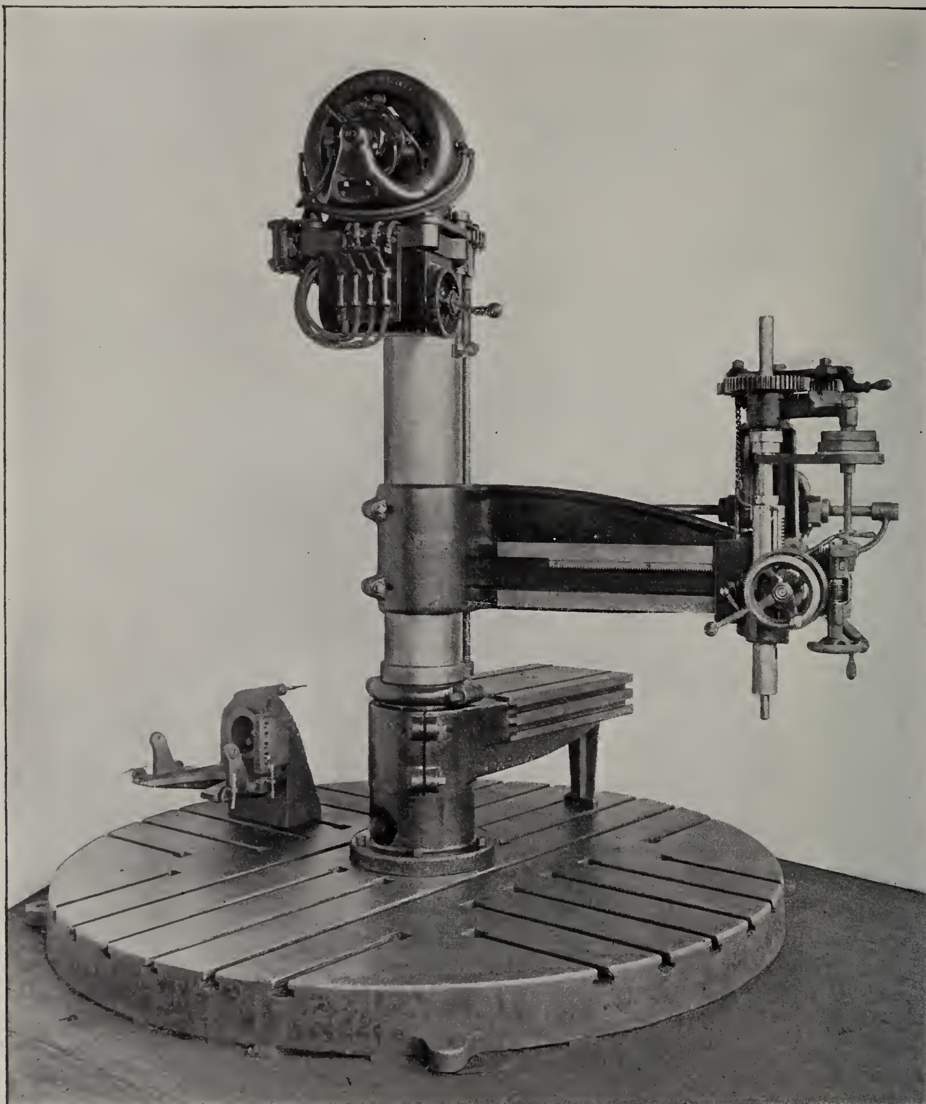


FIG. 25.—A CROCKER-WHEELER MOTOR, GEAR-CONNECTED TO A RADIAL DRILL PRESS, MADE BY THE PRENTISS TOOL & SUPPLY CO., NEW YORK

large power units are required it is frequently desirable to use synchronous motors. A synchronous motor is illustrated in Fig. 22. This is simply an alternating-current generator which is reversed in its functions and used as a motor. The synchronous motor must be provided with direct-current excitation for its magnetic fields, and it must be brought to normal running speed by an external source or by some special internal expedient. It is, therefore, ordinarily desirable for use only in large units. It has the valuable capacity of operating at unity power factor or at any other power factor which may be found most desirable under the conditions of its service.

Repulsion, series, and other types of single-phase, alternating-current motors

bid fair to occupy in the future an important place in factory power plants, and it is not improbable that the direct-current motor may ultimately find its now exclusive place in variable-speed work largely occupied by alternating-current machines.

A number of illustrations are introduced in connection with this article to which special reference is not made in the text. These illustrate various applications of direct and alternating-current electric motors to driving machines in various kinds of manufacture. The descriptive legends attached to these illustrations serve to explain the pictures.

It hardly seems fitting that an article of this character should close without a word regarding the sub-division of the driving units. This is a feature of factory drives which has been badly treated in the past, and does not always receive due consideration in the present.

The operation of every machine in a manufacturing establishment by its own individual motor produces a most satisfactory appearance; but, like many beautiful things, it may be an extremely wasteful and costly luxury. Very small motors are inefficient devices, and at the same time very expensive per unit of power developed, and it will frequently be found in manufacturing concerns which require in their business productive machines of small power that such machines will be most economically driven in groups, each group having its individual motor. The drive is then accomplished through the agency of a carefully designed and executed system of light belts, line shafts, and countershafts, with such mechanical means for speed variation at the machines as may be required. The solution of this question enters as one of the numerous features of the analytical consideration which should be undertaken when planning the system of power distribution for any important manufacturing plant.

Although no reference has been made to the electric lighting of manufacturing establishments, yet it should be noted that where the electric drive is employed, electric lighting is a natural accompaniment. No auxiliary machinery is required to furnish the lighting current, and frequently the power distribution circuits may be used jointly for power and lighting.

THE DISTRIBUTION OF ELECTRIC POWER FROM TRANSMISSION SYSTEMS

By Dr. Louis Bell

IN very many respects the sub-stations of a power transmission system are, in character and function, like ordinary generating stations for the public supply of electricity. Sometimes, as in cases where the transmitted power is received by motor generators and distributed over low-tension lines already erected, the similitude is very strong, and in the matter of general design it is always helpful to recognise it, but in the last analysis the comparison is apt to be misleading. The substitution of a motor for a steam engine as a prime mover actually implies, in a new station, something more than a change of driving power. It really means a new economic situation. This side of the matter has received less attention than it deserves, and, in fact, the writer himself must own to some degree of remissness in overlooking differences in the face of intrusive similarities. When the introduction of transmitted power involves, as it often does, changes far more radical than the mere abolition of engines, the value of comparison with ordinary central station working grows smaller rather than greater.

Failure to realize changed conditions is certainly responsible for some common faults in working transmission systems and for a certain lack of appreciation of the real value of transmission systems in general electrical supply. The utilisation of a distant water-power for the complete electrical supply of a city is a beautiful problem, but its complete solution is generally marred by a curious mixture of timidity and temerity, a hesitancy to push the work to its legitimate conclusion on the one hand and a willingness to take long chances in certain particulars on the other.

The general fault of power transmission systems, in the writer's experience, is lack of a proper appreciation of the conditions of regulation, and a singular lack of enterprise in dealing with this part of the work. On the other hand, there is no difficulty whatever in finding people who are willing to take all sorts of chances in the matter of voltage and line construction, which, above all other things, are the roots of success or failure in transmission plants.

The writer calls to mind, for example, a case in which a fairly long transmission for a city supply was undertaken. The owners of the plant were perfectly ready to play the limit in the matter of line voltage, generating plant, and hydraulic development, but when it came to the utilisation of the power they installed so extraordinary a mélange of motor-generators, rotaries, batteries, and auxiliary plants that the transmitted power demonstrably cost more than the power generated by steam in the central station, if the statements of the engineer when under oath be entitled to their proper credit.

This is doubtless an extreme case, but it is quite generally true that the distribution from a transmission system is the least progressive and most troublesome part of the entire plant, and that skillful and daring treatment of the distribution is rather rare. Yet on this

very point often depends the commercial value of the enterprise. The causes for such a state of things are various. Perhaps the most fruitful one is the traditional belief that alternating systems in themselves must be expected to regulate badly, and that the only means of escape is their abandonment at the very point where their good qualities are actually most valuable.

Still another cause is the ever-present and always ultimately disastrous desire to patch up an old system at the least possible expense rather than to gain the advantage of a better one at some additional investment. The result is to stave off the evil day of reckoning for a little, but to leave the plant as a whole in a condition that later demands the services of the surgeon rather than the nurse.

Given a reliable hydraulic power wisely developed and a modern polyphase generating plant, and there is no reason why the service, even at the end of a long transmission line, should not be of the most unexceptionable quality in all respects. If the service is not good, somebody has blundered or has been negligent. Above all things else, a transmission system needs intelligent engineering at every step of its development from its inception on. It is extremely easy for an unskilled superintendent to perpetrate blunders that are both exasperating and costly.

Good service implies a continuous and adequate supply of energy delivered at a closely uniform voltage. The first mentioned requirement depends upon the continuity of the transmission line itself and upon the distributing system as well. In this particular the plant behaves like an ordinary central station plus a long line over which the whole energy is delivered. It need hardly be suggested that for this reason the line is the last place in which to take chances.

In order to economise in cost of conductors and their erection, there is a constant temptation to reduce the factor of safety, both in insulation and mechanical strength. Raise the voltage and lighten the conductor so that you can skimp on poles, seems to be the present watchword of the alleged economist. Safety requires that whatever innovations are adopted the factor of safety should not be reduced. It is of very little use to build an elaborate station and then to connect it with the distribution system by a line that is just on the ragged edge of practicability. One line built thoroughly well and thoroughly inspected is safer than two lines skinned in cost and left to themselves in inaccessible situations. Two first-class lines are better than one, but the one is far more reliable than two poor lines.

An adequate supply of energy requires merely reasonable conservatism in taking on load. A hydraulic plant cannot be loaded beyond a certain point, and it is the business of the superintendent to keep inside of this load. A warning of this sort may seem altogether superfluous, but of late a good many hydraulic propositions have been developed in which the water supply is somewhat precarious and must be eked out by steam power. And between the two stools the consumer actually does get a bad tumble not infrequently. Another axiom of the business is that if one cannot afford to sell power at a certain price from either the hydraulic end of the plant or from the steam plant, no combination of the two can convert the loss into a profit. Auxiliary plants are often useful, but their true function is not to facilitate the acquisition of unprofitable load.

The commonest cause of inadequate supply, however, is a wrong estimate of the water supply. Nearly every reader of this article can call to mind instances in which a plant was installed where the minimum power proved on trial to be 25 or 50 per cent. less than had been estimated. For this reason, save on very well investigated streams, it is generally inadvisable to develop electrically beyond the power of the reputed minimum flow, unless one can obtain a market for surplus power. This is very difficult, for while hydraulic companies have for years sold "surplus," or "temporary," or "non-permanent" power, the customers of electric trans-

mission plants are generally less gullible or complaisant.

Given, however, a plant capable of providing a continuous and adequate supply of energy, and its power of supplying first-class commercial service is mainly a question of regulation. It is here assumed that the typical plant must be capable of undertaking all sorts of supply, and is not to be devoted solely to the operation of motors or rotaries. Even in these latter cases regulation is important, but the limits of voltage permissible are liberal enough to involve very few difficulties.

The question of regulation, then, must be regarded as the crucial point in the operation of power transmission plants for general distribution. This regulation must begin at the water-wheels and continue up to the last consumer. Fortunately, the regulation of the water-wheels is now a rather straightforward matter. An alternating system, whatever happens, must be held constant in frequency. In a central station the engines can be kept very accurately at speed, in which the central station had a distinct advantage until within a very few years.

To-day it is possible to regulate the speed of a water-wheel with entirely adequate precision, and the plant which dodges about and fools with "cheap and nasty" wheels and governors deserves no more sympathy than if it were equipped with old slide-valve engines, regulated at the throttle. But there is this difference, that, while nearly all respectable engines govern fairly well, it takes a good bit of skill and foresight to get equally good governing of a water-wheel. If, as too often happens, the job is left to an hydraulic engineer who has not had considerable experience with electrical plants, he is very apt to make a mess of it.

As regards the regulation of the generators themselves, a modern transmission plant is usually in better case than a central station of the ordinary kind. In fact, the engine-driven alternator is commonly inferior in both efficiency and regulating properties to the machines usually to be found in hydraulic plants. This is for the reason that most large engines being for slow rotative speed, an extreme multipolar design is generally adopted for the generator, and while this results in a very stately and imposing structure, every skilled designer knows that the slow rotation is secured at a considerable sacrifice.

In these days of steam turbines the case of the central station is somewhat bettered; but the turbine runs as much too fast for convenience as the huge engine runs too slow, although the generator design is somewhat less embarrassing in the former case. Alternators cannot be compounded with the facility that characterises direct-current generators; but, though the means of automatic regulation are more intricate in the former case, they are almost equally effective, and for various reasons the big polyphase generators of a transmission plant are usually designed in such wise that voltage regulation is relatively easy.

Up to the generator switchboard, then, the power transmission plant is in excellent shape as regards giving good service in point of regulation. Beyond this point the trouble begins, and the peculiar finesse requisite in power transmission engineering comes into play. The first material difficulty in distribution appears in the characteristics of the line. It is here assumed that the transmission is a fairly long one, twenty miles or more, so that the typical conditions are developed. As a rule, the copper in the line is figured at from 6 to 10 per cent. at full load, and the impedance drop is, as a whole, seldom less than 10 per cent. and sometimes 15 per cent.

Drop as great as that mentioned is not uncommonly found in low-tension distribution systems, and is, as a matter of experience, entirely compatible with service quite good enough to satisfy even a critical manager. But there is an important difference between the cases in favour of the central station; there the large losses are found on various individual feeders, from the ends of which it is no difficult task to bring back pressure wires, or upon which the pressure can be proportioned to the current supplied. These feeder drops are some-

times 20 per cent. or more in the older plants, and yet they can be handled successfully. In the transmission plant it has proved to be a rather difficult matter to regulate automatically the pressure at the end of the line, with the result that too heavy a burden of regulation is laid upon the sub-stations. In actual plants the main line total drop may vary from 1 or 2 per cent. to 12 or 15 per cent. during various parts of the day, and the power factor may shift from 0.60 to 0.85 or 0.90.

It often happens, moreover, that a transmission line must furnish power not only at the terminus, but at intermediate points, and it cannot be simultaneously regulated for two distant loads. Hence, it generally happens in practice that the sub-station of a transmission plant acts like a central station in which the generator voltage is somewhat inconstant. In most transmission plants which use step-up and step-down transformers one must add 4 or 5 per cent. to the estimate of variation just given.

This situation gives rise to some very interesting problems and has driven engineers and superintendents to all sorts of subterfuges. Now and then some weak-kneed brother throws up the sponge, puts in a separate lighting transmission line and distribution system with plenty of copper, and, regulating this carefully at the sub-station, lets the power line take care of itself.

Conditions sometimes arise in which a separate power line may be necessary, as when a large proportion of the plant is used on a railway or other extremely variable load; but in the majority of instances separating the services is merely a confession of gross incapacity on the part of the management. It is costly, considerably lessens the effective capacity and the flexibility of the plant, and often leads to bad motor service. It is quite true that a large motor load may produce trouble in the regulation, but it is equally true that it need not do so if one exercises the same discretion in a distribution from a transmission system as in ordinary central station work.

Most of the difficulty in motor service is customarily laid at the door of the induction motor, a small part of it justifiably, the major portion quite unjustly. In nine cases out of ten it is not the motor that is at fault, but the fool behind the installation thereof.

No reasonable man would expect on a low-tension lighting system to put a 50 horse-power motor running a sawmill at the end of a long lighting circuit without impairing the service, yet the same person displays a singular tendency toward installing an induction motor in such fashion, and then damns the polyphase system up hill and down dale because the lights flicker. Or he allows a motor to go in without starting devices adequate to the conditions, while if somebody proposed to put in a continuous-current motor without a starting-box, and fused with wire nails at that, service would be promptly refused or cut off. In other words, people otherwise sane and of good judgment seem to have a fatal tendency toward putting induction motors through all sorts of outrageous stunts which their common sense would forbid if they were dealing with continuous-current machines.

It is perfectly true that an induction motor will stand up under abuse that would be fatal to its older cousin; but the concomitants of such abuse do not, to put it mildly, make for good service on the distribution system.

Granting a system operated for general distribution for power and lighting, and operated from the sub-station of a transmission line, the requirement fundamental for good service is proper design of the distributing lines. If at the sub-station the energy is transformed for distribution as continuous current, it is generally safe to say that the net-work will be properly laid out, for the bitter experience of years has taught the necessity of providing an adequate amount of copper.

But the devil-may-care influence of the old house-to-house alternating-current methods is still strong upon the art, and it is singularly difficult to persuade the organisers of an alternating distribution to pay the necessary tribute

to Ohm's law. Of course, the reactance drop has to be reckoned with also; but its practical effect is mainly felt in the requirement for somewhat larger margin of capacity in the regulating devices, while the total drop is generally no larger than has to be dealt with in a low-tension, continuous-current, net-work, and the scope of the alternating regulation, therefore, is about the same, while its efficiency is considerably greater.

In the matter of economical location, the sub-station has a very considerable advantage over the central generating station. It is free, save as it may be the location of a steam auxiliary, from the severe requirements regarding coal and water which so inconveniently limit the situations available for steam stations, and enjoys the further advantage of being so compact that the cost of real estate is relatively small. Transmission plants seldom reap the full advantage of these properties, but they ought to do so. It often happens that there would be considerable gain in cost and quality of service by using two or three sub-stations instead of one, although, save in railway distributions, the advantage is seldom appreciated.

This question of auxiliary plants is one which in modern transmissions assumes no little importance, and is the source of many worries. Auxiliaries may be required for three quite distinct purposes, each of which points at special directions of development. First, an auxiliary plant may be required purely for use in emergencies to carry more or less of the load, in case of premeditated repairs to the main line plant or in the sub-station. Second, it may be required to help the plant over the peak of the load now and then, as well as for the former purpose. Third, it may be installed to assume part of the normal load at certain seasons of the year. In each case it is available to a certain extent in the event of an accident to the system.

The auxiliary plant of the first class is established for purely temporary use as a convenience in the ordinary contingencies that arise in every hydraulic plant. It is not intended to assume any considerable part of the load, but to go into use at times when the load is normally light, as during a part of Sunday or during the very early morning before the motor load comes on.

It happens now and then that some repairs must be executed which cannot be put through without a temporary shut-down, the time for which can be chosen beforehand. A comparatively small auxiliary, perhaps not more than 10 or 15 per cent. of the full load capacity of the system, will answer admirably for this simple purpose, its proper size being determined by the characteristics of the load. Cheap and simple apparatus will answer the purpose here, for in such temporary use the matter of operating economy is secondary. A small steam plant at or near a sub-station is the simplest way out of the difficulty in many cases, although there is much to be said in favour of a storage battery and reversible rotary, particularly if the plant is hard pushed at times of maximum load.

The battery has, during the last few years, passed from a condition of doubt and uncertainty into clear recognition as a valuable adjunct in central station operation. If a transmission plant has a bad peak in its load line a battery can be put to extremely good use in furnishing both an auxiliary in case of needed repairs and a source of additional power during the peak. It is far better suited to this use than to assume merely the function of an occasional auxiliary, or that of a reserve plant during periods of low water, or the like. The first cost of the battery is rather high, and to keep it in first-class order it should be regularly used. If the conditions of the load demand, therefore, a very large use of the auxiliary, or very infrequent use, or both, the battery works somewhat at a disadvantage.

When, on the other hand, the chief use of an auxiliary plant is to deal with periods when the transmission plant is suffering from low or high water, a steam plant becomes a necessity, unless local conditions are such as to give the big gas engine an advantage over steam.

Hydraulic plants vary greatly in their

need for this kind of assistance. In some instances the serious shortage covers only a few days in each year, and the lesser shortages can easily be covered by storage. In other cases there may be a month or so of moderately low water during which help is needed. Again, some plants suffer only during a few days of flood, which backs up the water and reduces the working head. Each case has to be treated on its merits, and there is a gradual passage of the conditions toward those in which more or less auxiliary power is needed most of the time. Such mixed power plants are rather in a class by themselves, and a volume might be devoted to their development.

Whatever the character of the auxiliary may be, save in rare instances, it belongs at the receiving end of the lines, and may properly be attached to a sub-station. This, to a certain extent, limits the choice of locations if the auxiliary is steam-driven, but generally the sub-stations can be located in better relation to the centre of load than ordinary generating stations. To obtain full advantage of location it is necessary to bring the high-tension lines fairly in toward the centre of load, though, with a wisely laid out primary net-work, displacements are far less serious than in a low-tension plant.

At the present time there is a strong and rather unreasonable prejudice against bringing a transmission line well in on overhead poles, so that it may become necessary to install high-voltage cables. These are now fairly reliable, but at modern line voltages it is usually wise to sacrifice something in sub-station location for the sake of bringing in the aerial line. Although transmission lines carry very high voltages, they are, from necessity, generally so well built as to be relatively quite the safest part of the system, far safer, for instance, than arc-light lines.

Given, then, a transmission line brought into a sub-station fairly well located, the question of good service resolves itself into the matter of suitable regulation of the voltage. This involves taking care of a total drop of, say, 10 per cent. in the main line, and perhaps 5 per cent. more up to the services. Indeed, the total drop, inductive and other, is sometimes even greater than this. The vital question of good service is the management of this drop.

The simplest case is that of a single sub-station near the centre of load. Given this condition, the policy most often successful is to give the generators automatic regulation for the preservation of constant pressure at the sub-station, and then to use manually-operated regulators on the feeders at the station. It is best to carry the automatic regulation through to the secondary side of the reducing transformers so as to lessen the work required in feeder regulation.

This process is equivalent to the ordinary regulation of a low-tension central station, except that it involves less loss of energy, and is fully competent to give first-class regulation at the services. But in order to give this the work of feeder regulation must be carefully and thoroughly done, and just here is where many transmission plants fall down. In other words, they follow too often the bad example of the early alternating plants instead of the good example set by the large continuous-current stations.

Ordinarily the regulation problem is complicated by the distribution being over two or three-phase circuits which require separate regulation or are more or less interdependent. But the same sort of thing also occurs in ordinary three-wire systems, and, after all, is merely the holding of regulation on certain feeders. It is not difficult, in the main, to balance a polyphase load, and after that is done the variations are simply those due to a certain wandering of the load during the periods in which the total load is changing rapidly.

There have been several attempts at automatic regulators for sub-stations, planned to take care of unbalancing as well as general variations, but they have not as yet met with very gratifying success. Nevertheless, careful feeder regulation will do the work and do it well.

If two or more sub-stations are involved, the same general principles will lead to success. It is not difficult to

plan for approximately equal drop on the main line to the several adjacent sub-stations, and the situation is then similar to that found in a large low-tension system fed by several stations.

The peculiar difficulties of a transmission plant arise when the several sub-stations are widely separated, either along the same line or on separate lines from the same generating station. In such a case the regulation from the generating station cannot easily be made to give constant voltage at the several sub-stations. If these are on separate lines they can be run from separate sets of generators, and regulation is then easy, but at the cost of some, and often considerable, loss of capacity, since each line must have, in the main, an independent reserve capacity.

If the several lines had about the same drop and kind of load they might be regulated by general average; but in widely separated sub-stations the loads almost always have different characteristics, so that a common regulation will not be successful. It is, therefore, generally necessary to increase the range of the sub-station regulation so as to take up the variations in the voltage of supply. If only one sub-station carries a mixed load, and the others merely motors, that one can be given constant voltage, letting the others take care of themselves; but if there are two or more mixed loads, it is either a case of considerable extra care in feeder regulation or the lines must be worked from independent generators.

The commonest and most difficult case is that in which the same long transmission line gives service for two sub-stations with mixed loads, one at the end of the line and the other, perhaps, midway, with possibly still other stations at other points. In this case it is obviously impossible to give automatic regulation for more than one point along the same line, and the variations of voltage are apt to be embarrassingly large. Sometimes the trouble may be dodged by duplicate circuits, as under the conditions just discussed. Failing this, it is rather difficult to give good service without resort to somewhat drastic remedies.

If only two sub-stations are concerned the generating station regulation may be carried to one or the other or to some intermediate point as convenience dictates; but the inevitable result will be the necessity for very careful hand regulation over an unpleasantly wide range.

To meet such cases the problem of automatic feeder regulation on polyphase distributing circuits ought to be worked out. At present, attempts in this direction have been very limited in their success; but an automatic feeder regulator is certainly the one piece of apparatus most badly needed in general power transmission. The conditions to be met are somewhat severe, but the thing can undoubtedly be done. Lacking this, various more or less useful makeshifts have been tried, but seldom with entirely satisfactory results.

Good hand regulation at the feeders is effective, and can, so far as the operator is concerned, be carried over any range that is necessary in a well-designed transmission system. Most sub-stations, however, are not properly equipped with regulating apparatus, let alone pressure wires or their equivalent, and it is to this neglect to provide the necessary apparatus that most of the bad service charged against transmission plants is due.

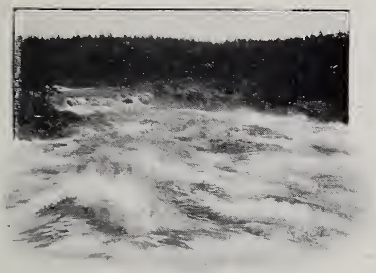
With properly equipped sub stations there is no reason why a transmission plant distributing entirely upon the polyphase system should not give service in every way equal to that obtained from the best low-tension central stations. If it does not do so, the reason may be sought in insufficient attention to necessary details.

There are many transmission plants in which it is not necessary to follow every central station precaution, but wherever a lighting and power distribution on a large scale is attempted nothing that makes for good service should be considered as unnecessary. The large work of the future is going to depend very greatly upon long-distance power transmission, and there must be no shirking of responsibilities.

ELECTRIC POWER FROM SHAWINIGAN FALLS, CANADA

PART I.—THE HYDRAULIC DEVELOPMENT

By Wallace C. Johnson, Chief Engineer of the Shawinigan Water & Power Company



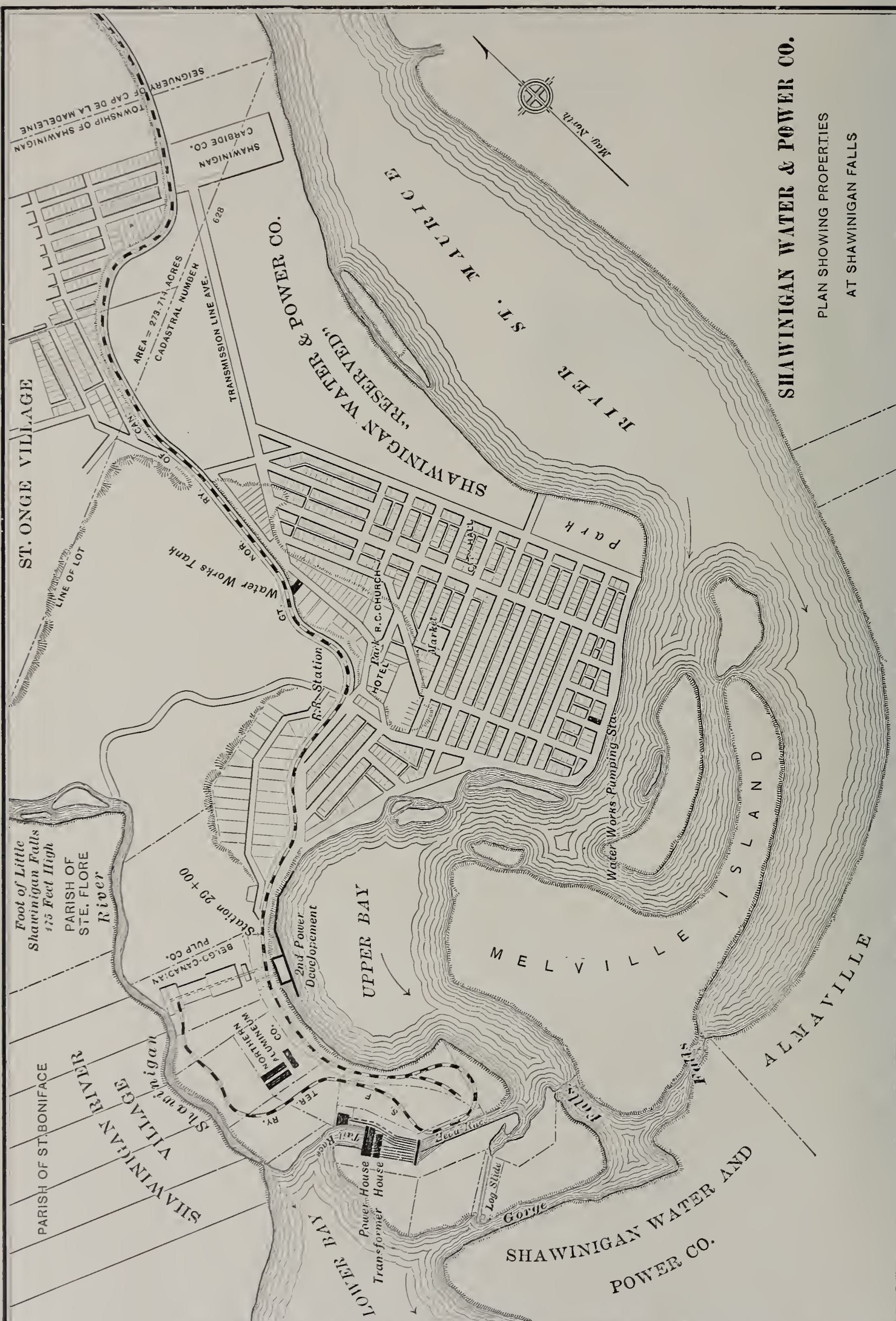
ST. MAURICE RIVER CASCADES

WHEN a band of traders and adventurers, under Samuel de Champlain, established their headquarters at Quebec early in the seventeenth century, the first outpost they established was at a point about 90 miles further up the St. Lawrence River. There they opened a trading post, and there also came Recollet monks, to whom the Pope had given charge of the work of christianising the Indians in America. This post they named Trois Rivières, from the fact that at that point a river, now called the St. Maurice, empties into the St. Lawrence through three different channels. The year before his death Champlain built a fort at this point, and in the same year the Recollet monks built for themselves a frame house, probably the first frame building in Canada outside of Quebec. The reason for establishing the post at this point undoubtedly lay in the fact that the St. Maurice afforded a highway into the northern region, rich in furs.

As the trader of those days journeyed up the river in his canoe or bateau, about 15 miles from the post he came to a beautiful lake, approximately two miles long and about a mile broad. Passing over the portage at the head of this lake, less than a quarter of a mile in length, but making a rise of 140 feet, he came to another lake, narrower than the first, but stretching away to the north upwards of five miles. From the south end of this upper lake the river flows over a beautiful cascade, towards the south at first, but turning completely around as it plunges downward over the cascade and through a narrow gorge, emptying into the lower lake and flowing towards the north. As the water poured down over the rocks the spray was dashed up in sheets, and the Indians, seeing in it a resemblance to their own lace work, gave the name Shawinigan to the cascade, and "Chutes de Shawinigan" the Frenchmen continued to call it. At the head of the lake was a short section of rapids, and, about four miles further on, a fall of about 40 feet. Passing this fall the river became a broad and deep stream for upwards of 75 miles, affording an easy highway into the depths of the wilderness 100 miles north of the St. Lawrence.

In the early history of this region it was discovered that by a few portages around the various falls the headwaters of the St. Maurice could be reached about 350 miles from its mouth, and that from this point a comparatively short portage over the divide brought the traveller into Lake Mettagami; from this lake, still journeying north through the Metchiskan and Nottaway rivers for about 300 miles, St. James Bay was reached, and thence Moose Factory, one of the principal posts of the Hudson's Bay Company.

A trader, familiar with the St. Maurice River 275 years ago, in passing over

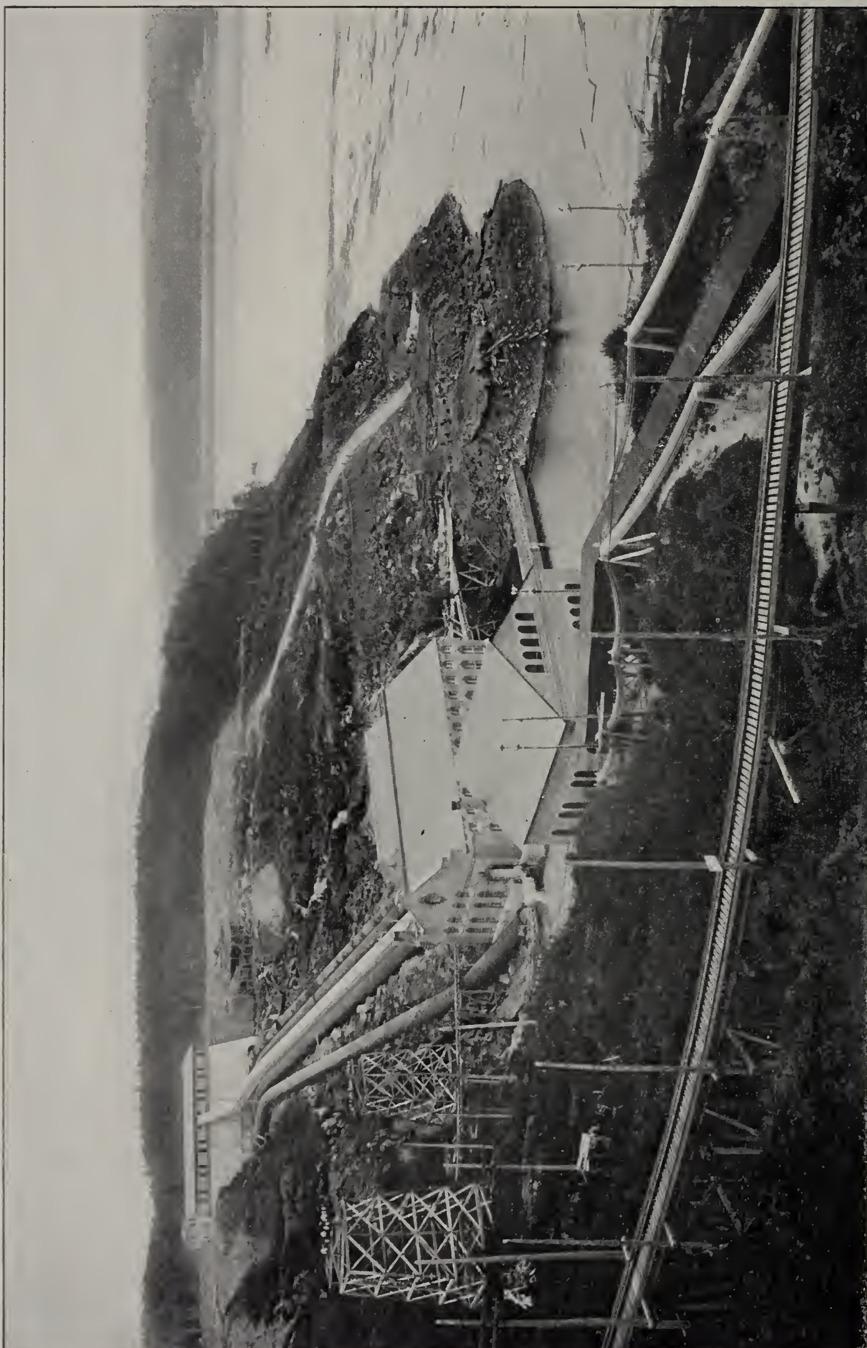

SHAWINIGAN WATER & POWER CO.
PLAN SHOWING PROPERTIES
AT SHAWINIGAN FALLS
Mag. North
ST. MAURICE
RIVER
SHAWINIGAN WATER & POWER CO.
"RESERVED"
SEIGNEURY OF CAP DE LA MADELEINE
TOWNSHIP OF SHAWINIGAN
SHAWINIGAN CARBIDE CO.
628
AREA = 273.714 ACRES
CADASTRAL NUMBER
TRANSMISSION LINE AVE.
ST. ONGE VILLAGE
LINE OF LOT
CAN. NOR. RY. OF
GT.
Water Works Tank
Park
R.C. CHURCH
HOTEL
Park
Market
CITY HALL
R.R. Station
Water Works Pumping Sta.
MELVILLE ISLAND
ALMAVILLE
UPPER BAY
2nd Power Developement
Station 29+00
BELGO-CANADIAN PULP CO.
NORTHERN ALUMINEUM CO.
Foot of Little Shawinigan Falls 175 Feet High
PARISH OF STE. FLORE
River
Shawinigan
PARISH OF ST. BONIFACE
RIVER
SHAWINIGAN VILLAGE
TER. RY.
S. F.
Tail Race
Power House
Transformer House
Head Race
Log Slide
Gorge
Falls
LOWER BAY
SHAWINIGAN WATER AND POWER CO.

the route to-day would find most of it practically unchanged. At the mouth of the river he would find the house of the early monks still standing and still occupied by religious men, though of a different sect and order. At some points along the lower part of the river he would find the land cleared and under cultivation, but after passing the falls, about 25 miles above the mouth, he would find the country as he had left it nearly three centuries ago. The old highway from St. James Bay is still in use,—provisions going in and furs coming out as in his day, except that they are now landed above the falls and transferred to a railroad. He would observe a very notable addition to the business of the river in the large number of logs which it carries from the forests at its headwaters and tributaries to the mills along the lower twenty miles of its course.

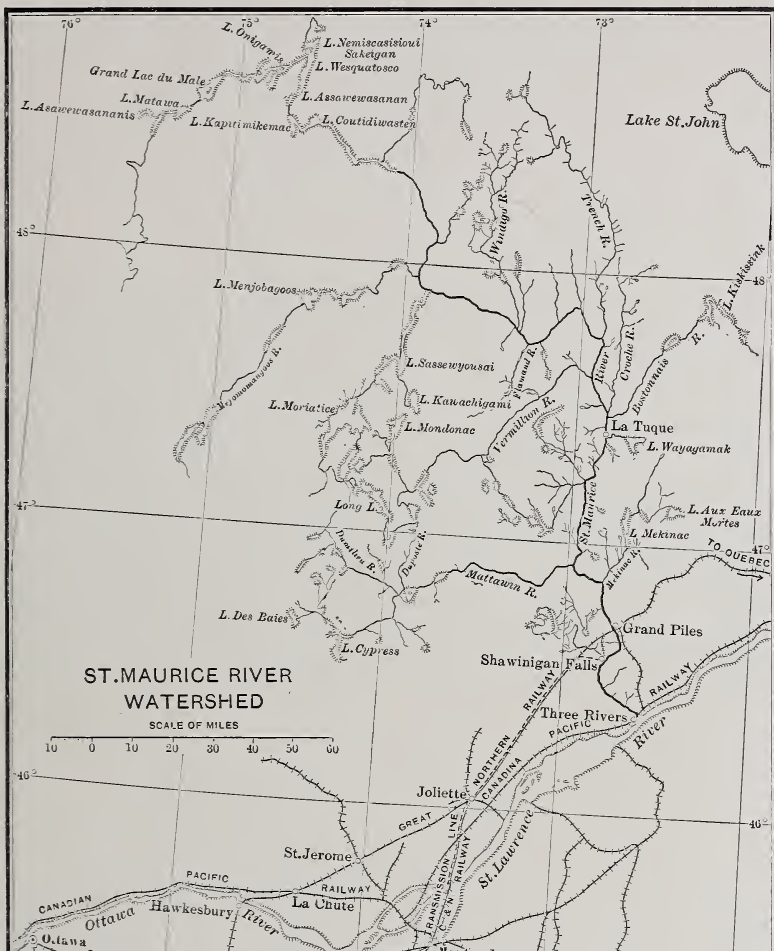
The greatest change he would find at the falls of Shawinigan where the works of the Shawinigan Water & Power Company are located,—the subject of this article. On October 29, 1897, Mr. John Joyce, of Andover, Massachusetts, purchased from the Canadian Government the right to the use of the water of the river for power purposes, and shortly afterwards, with Mr. James N. Greenshields, K. C., of Montreal; Mr. J. E. Aldred and Mr. H. H. Mellville, of Boston, and others, organised the Shawinigan Water & Power Company.

THE HEAD RACE IS ABOUT 100 FEET WIDE AND 1000 FEET LONG

In the original purchase of Mr. Joyce there were included the islands in the lake at the head of the falls and the land in the bend of the river immediately adjacent to the falls. Desiring to have sufficient land for factory sites and for the houses of the operatives and managers of the various industries which, it was believed, would be located in the vicinity, the power company and the individuals connected with it have since



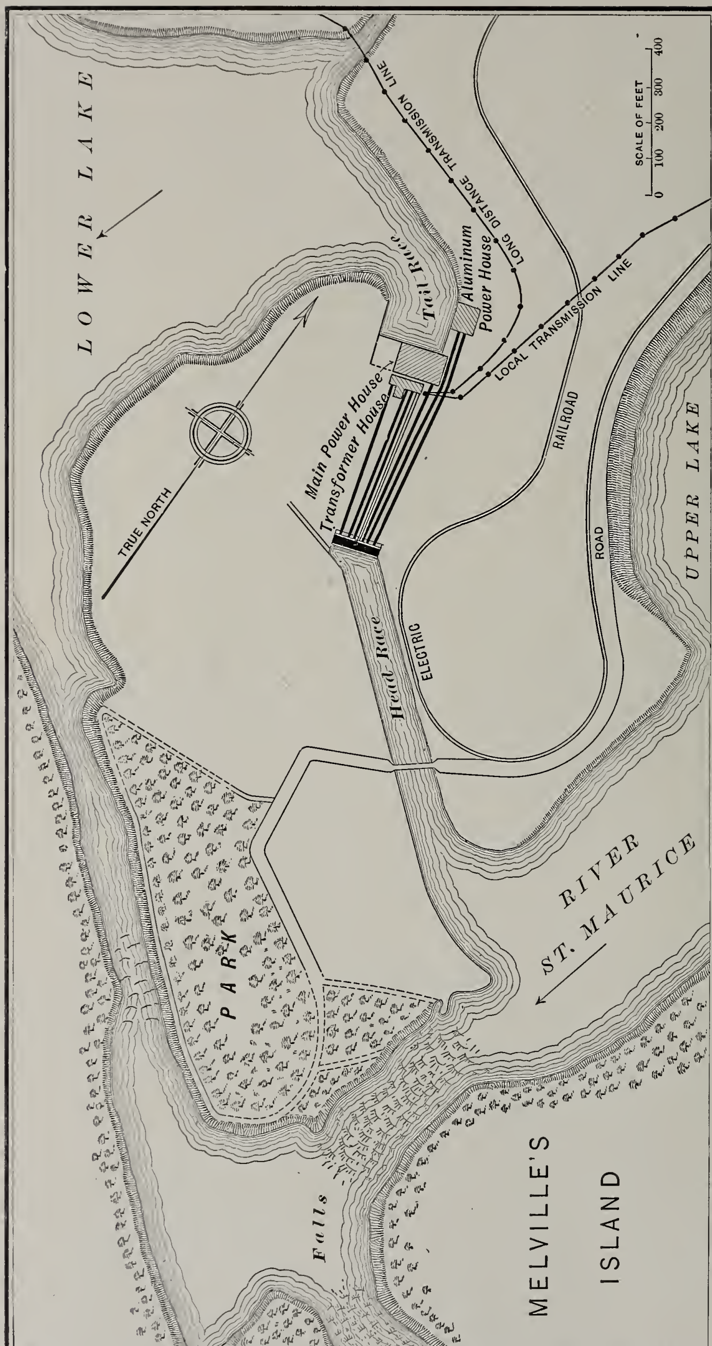
THE POWER HOUSE OF THE SHAWINIGAN WATER & POWER COMPANY. THE CANAL FROM THE ST. MAURICE RIVER FALLS ENDS ON HIGH GROUND, 125 FEET ABOVE THE POWER HOUSE. THE ULTIMATE CAPACITY OF THE FALLS IS OVER 100,000 H. P.



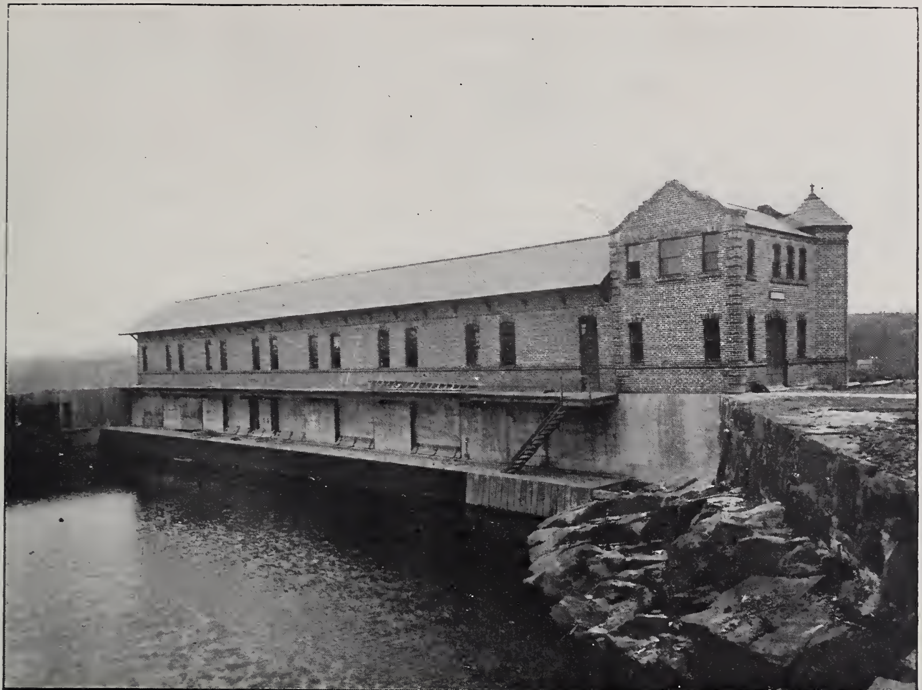
purchased all the land on both sides of the falls and for a long distance up and down the river, amounting to about two thousand acres.

On the occasion of the writer's first visit to the falls of Shawinigan early in 1898, which was made for the purpose of devising a general plan for developing the power, the nearest approach to the falls by rail was about five miles; but this was over a railway on which passenger trains were run only weekly, and it was, therefore, better to drive about twelve miles from the nearest railway station to which trains ran more frequently, the last part of the distance being over a private line. Arriving in the vicinity of the falls, there still remained a walk of half a mile or more to reach the lower lake. Embarking there in a boat propelled by a stalwart Indian, we were landed at the foot of the old portage, over which we walked to the head of the falls.

The whole country was heavily wooded, and the most prominent feature in the landscape was a shrine established on the top of a hill close to the falls, the trees having been cut away so that the cross of the shrine was visible for a long distance up and down the river. It was found by survey that the channel, which



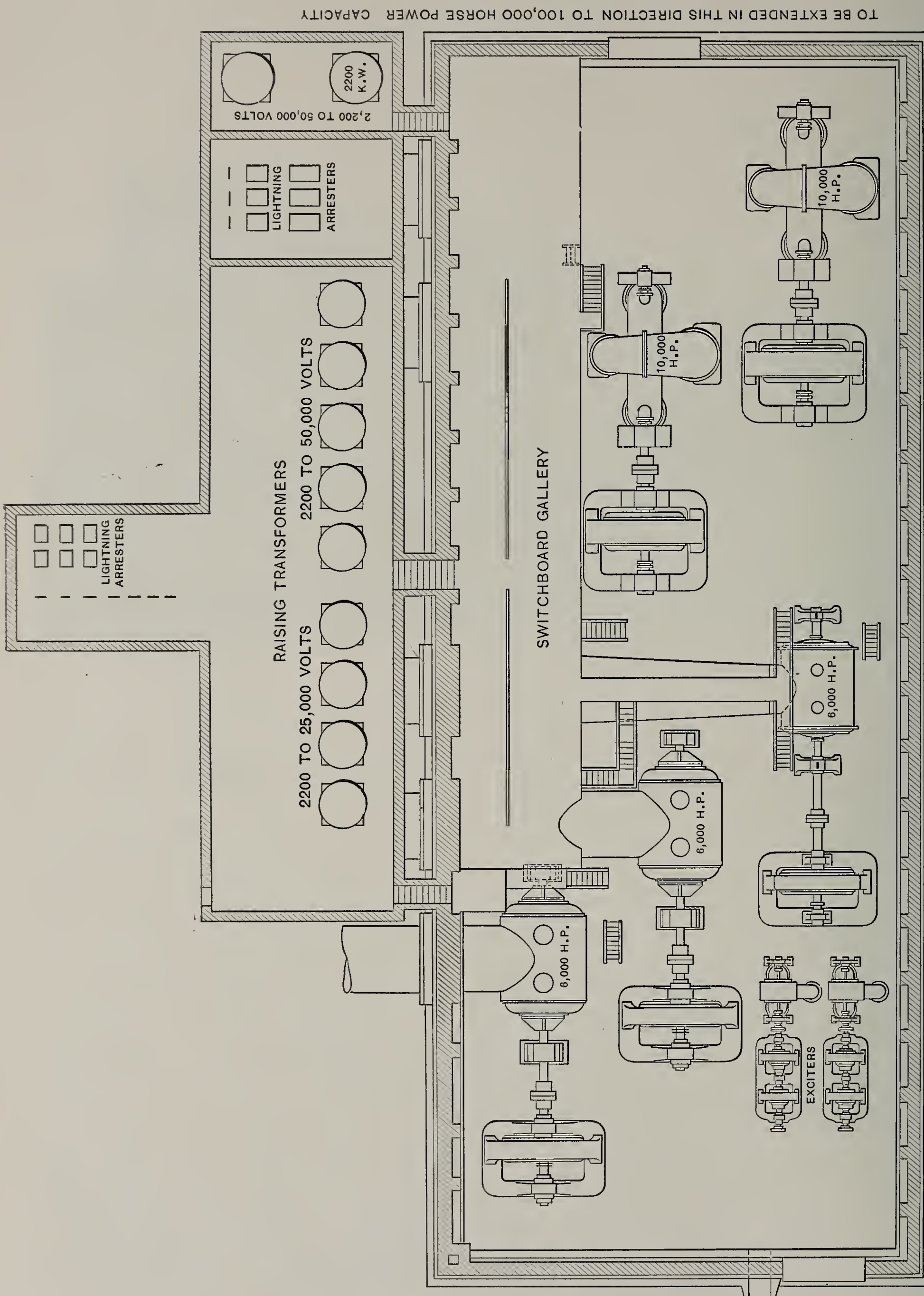
AN ENLARGED MAP OF THE SHAWINIGAN POWER PLANT, SHOWING MORE CLEARLY THE LOCATION OF THE TRANSFORMER AND POWER HOUSES, THE PENSTOCKS, AND THE HEAD AND TAIL RACES



THE END OF THE HEAD RACE, HERE SHOWN, IS CLOSED BY A CONCRETE WALL CONTAINING OUTLETS FOR THE PENSTOCKS

was about 1000 feet in length and 600 feet in width, leading from the upper lake to the head of the falls, was 20 feet in depth right up to the brink of the falls where there was a natural ridge of rock about 20 feet high over which the water flowed, forming the crest of the falls. Through this channel the water flowed at the rate of about 3½ miles an hour at ordinary stages of the river. To the west of this channel the ground was practically level and of rock formation for about a thousand feet. From the western edge of this level a steep slope of hard granite rock dropped 140 feet to the level of the lower lake in a horizontal distance of about 500 feet. In view of the fact that a river, reaching as far to the north as the St. Maurice does, would, in the spring, carry large quantities of ice, and in view of the greater stability of a canal excavated in the rock, it was decided to take the water out of this channel, where there was a considerable current, rather than out of the lake itself, where the canal would have been shorter, but through a clay formation.

It was impossible at that time to determine closely the low-water flow of the river. The St. Maurice River drains an area of about 18,000 square miles, consisting almost entirely of forest land so thickly interspersed with lakes that it is possible to journey through it in almost any direction with a canoe, making only short portages. The sources of the river are 300 miles north of the St. Lawrence, and information obtained from the log drivers indicated that the floods due to the melting of the snow, which during the winter covers the ground to a depth of 6 to 10 feet, were not over until late in July. From these and various other data which were obtainable as to the fluctuation of the river, the writer estimated that the low-water flow would not be much less than 10,000 cubic feet per second, and that it would be possible to obtain an actual



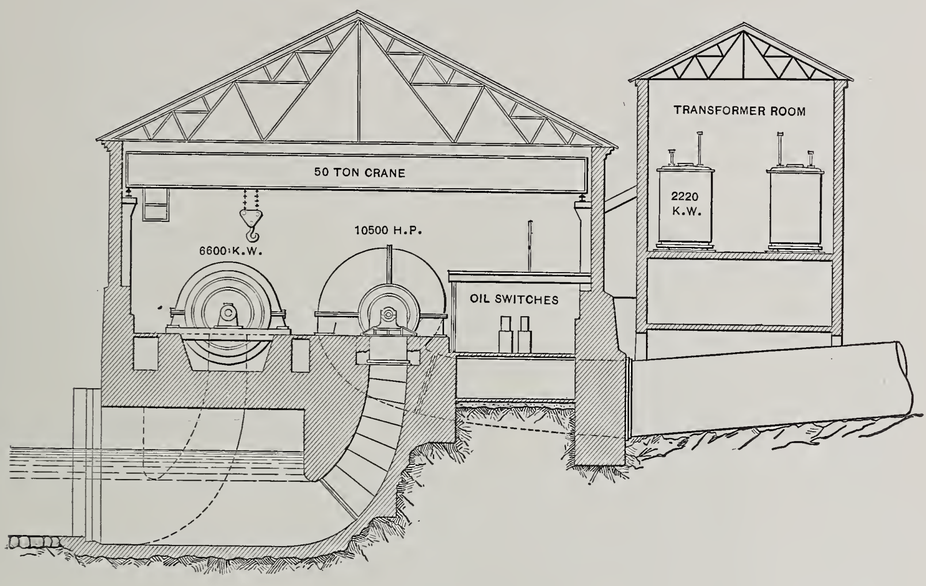
A PLAN OF THE POWER HOUSE AT SHAWINIGAN FALLS

working head on the water-wheels of 130 feet. Therefore, a development of 100,000 horse-power could properly be made, relying on the natural flow of the river.

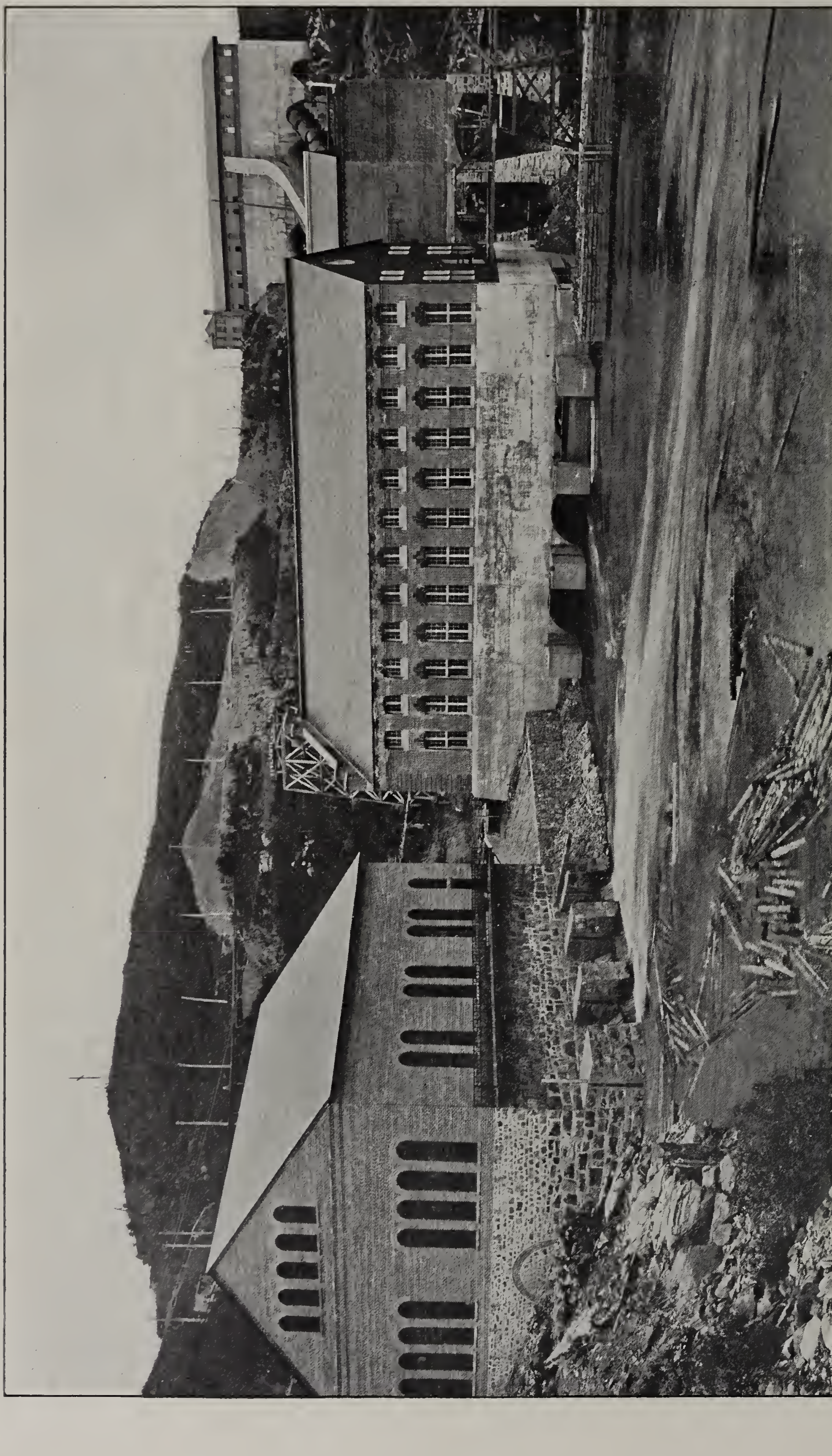
Nothing like an accurate measurement of the flow of the river has yet been made, but from observations by means of current meters and floats in the natural channel of the river estimates of the low-water flow have been made which seem to confirm the original ones, —practically 10,000 cubic feet per second. The fluctuation between extreme high and extreme low water in the upper lake is about 15 feet. It is entirely practicable to construct a dam on the ridge of rock forming the head of the falls, with sluice gates for the flood water. This dam will maintain the low-water level at the height of the flood water, thus adding about 15 feet to the head at time of low water.

The lower lake fluctuates even more than the upper lake, its low-water level being somewhat more than 150 feet below the high-water level of the upper lake. The many large lakes in the water shed render the construction of reservoirs of large capacities a very simple matter. The ultimate capacity of the water power at Shawinigan Falls is, therefore, largely in excess of 100,000 horse-power.

In May, 1899, work was commenced by the contractors, the Warren-Burnham Company, of the city of New York, under the direction of Messrs. T. Pringle & Son, engineers, of Montreal, upon the excavation of a canal about 1000 feet in length, 100 feet wide and 20 feet deep below low-water level. For about half the length of the canal, nearest to the river, the natural rock is about level with the surface of the water, and for the balance of its length the surface of the rock slopes off to about the level of the bottom of the canal at its west end. Along the north side of the canal, as shown in the illustration on page 189, a dry wall was built on top of the rock to about the high-water level. On the south side of the canal a timber crib work was built, well filled with loose stone and planked on the canal face, with a view to the possible widening of the canal in the future. The canal was closed at its west end by



CROSS SECTION OF THE POWER HOUSE



ANOTHRR VIEW OF THE SHAWINIGAN POWER PLANT BUILDINGS

a concrete wall 40 feet in height, containing outlets for six penstocks, 9 feet in diameter; this wall it is intended to extend to the south as additional penstocks are required, the canal being widened accordingly at the west end.

On the completion of the canal and forebay, the writer, who had previously been employed in a consulting capacity and had already prepared the plans for the power house, assumed entire charge of the work as chief engineer of the Shawinigan Water & Power Company.

The capacity of the two most northerly penstocks, —10,000 horse-power,— was disposed of to the Pittsburgh Reduction Company, of Pittsburgh, manufacturers of aluminium, who decided to build their own power house and install their own water-wheels and direct-current generators, to generate current for use in their reduction process without transformation.

This power house, which was also designed by the writer, and the company's works are located on the east side of the tail race, as shown in the plan on page 188, the works being within 800 feet of the power house. They have at present installed three water-wheels, each of capacity sufficient to drive two 1000-KW, direct-current generators, one being coupled to each end of each water-wheel shaft. The three wheels are supplied with water from one penstock. It is intended to install two additional wheels and also an additional penstock. The plant will then be so arranged that two of the wheels will be connected to each penstock, and one wheel, the centre one in the power house, will be connected with both penstocks with valves in the supply pipe of each wheel, so that in case the water is shut out of either penstock, three wheels will still be available for use.

Each of the wheels of the Pittsburgh Reduction Company consists of a pair of inward flow turbines which take water at the bottom of the case and discharge it through quarter-turns and draught tubes at each end of the case. Each wheel is provided with a valve at the intake, by means of which the water can be shut off from it while the others are in operation. A 300-volt direct current from the generators is carried directly to the reduction room,—a total length of 700 feet,—over aluminium rods 3/8 inch in diameter. The conductors on each side consist of 200 of these rods.

To the main power house penstock pipes, 9 feet in diameter and 450 feet long, run in a north-easterly direction from the forebay. In the design of the power house the starting point was the generator. A study of the probable use of power included a transmission to Montreal, 85 miles distant, and to other points nearer by, for power and lighting, the operation of railways and the furnishing of current for electrochemical industries, which, it was believed, would be attracted to Shawinigan by the cheap price at which power would be sold. As some of these users would require alternating current for smelting purposes, and others direct current for electrolytic processes, a frequency of 30 cycles was fixed upon, while a unit of 5000 horse-power at the generator terminals was selected as being a convenient and economical size for a power plant of the probable capacity of this one.

The point which called out more discussion than any other in the design of the power house was whether the water-wheel and generator units should be of a vertical or horizontal-shaft type. After careful investigation of the matter the directors decided upon a horizontal shaft type, for the reason, largely, that they believed the practical mechanical operation to be more reliable, and realised that continuous and safe operation is an important factor in the design of any central power station. For the same reason a speed was adopted which would not require forced lubrication of bearings and which would permit of the simplest design of water-wheel and generator. The speed was fixed at 180 revolutions per minute, and the revolving field type of generator, generating current at 2200 volts, was adopted. A water-wheel was designed of sufficient capacity to provide for a loss in the generator of 2½ per cent. and an overload of 15 per cent., mak-

ing the water-wheels of a capacity of 6000 horse-power.

The elevation of the main floor of the power house was established slightly above the level of high water in the lower lake, as near as could be determined from the observations which it was possible to make at that time; that of the shaft of the water-wheel was fixed at about 3 feet above the floor. The outside diameter of the armature ring of the generator being 14′ 10″ brought the centre pit of the generator foundation 7½ feet above this level. Great care was, therefore, taken to make the generator pit and the outlets for the cables watertight. Although the basement floor was 9′ 8″ feet below this level, and parts of the water-wheel were below the level of the supposed high water, care was taken in the design of the first two units and their appurtenances not to install in the basement any apparatus whose operation would cease should the basement be flooded.

The basement walls of the power house were constructed of concrete of sufficient thickness to withstand the water pressure, and great care was taken to make the concrete construction tight. It was carried up to the windows, about 3 feet above the floor of the power house. The operations during the past two years since the power house was completed have shown that there is no trouble in keeping the basement dry, even when the floods are as high as the main floor. A small triplex pump, driven by a 5 H. P. motor, has kept the basement perfectly dry during two such flood seasons. Auxiliary pumps of larger capacity have been installed, and are in readiness in case of a considerable leak, but they have not yet been used. It is, therefore, considered safe to place the electrically-operated switches and cables, now being installed and shown in the section on page 195, considerably below the high-water level.

Depending upon such records as were obtainable when the power house was built, the first three units have been installed with the lower end of the draught tube at a level which gives a working head varying from 130 to 135 feet, except during the short time in each year when the level of the lower lake stands above the bottom of the draught tubes. It has been found, however, by observation since the first design of the power house, that the low-water level of the lower lake is so much lower than was at first supposed that the water-wheels to be installed in the future will be set upon a lower level, making it possible to utilise 135 feet head at low water. Should the low-water level of the upper lake be maintained at high-water mark, as above suggested, 135 feet head will be available at all times, except during the short high-water periods, when it may be reduced to 125 feet. Under this increased head 10,000 cubic feet per second will be sufficient to develop 125,000 horse-power.

On pages 194 and 195 are shown a general plan of the main floor of the power house and the transformer house, and a cross-section of the two buildings. These plans show the general arrangement which may be continued indefinitely to receive all the units which it may hereafter be decided to install.

The first three units were installed in three lines lengthwise of the power house, the water-wheels being placed so as to permit the penstocks of each wheel to pass the others. They all take water at the sides of the cases and discharge through single draught tubes. The first two are Francis turbines without gates on the pressure side, butterfly valves in the draught tubes taking the place of the usual gates. This arrangement was adopted with a view to the close governing of the wheels, the penstocks being of considerable length.

The usual form of water-wheel gate controlled by a governor operates to check the velocity of the water in the penstock when it is desired to decrease the speed of the wheel. Thus, momentarily raising the acting head on the wheel tends to increase its speed. By throttling the discharge in the draught tubes the partial closing of the gate by the governor tends to create a pressure in the vacuum chamber. This decreases the head acting on the wheel, thus governing the motion of the wheel, without

changing the amount of water discharged, to the same extent as in the case of apparatus governing the speed by throttling the water supplied on the pressure side. As will be noted in the illustration on page 200, large vent pipes have been erected in the penstocks about 300 feet from the wheels. No trouble has been experienced from momentum effects.

From a study of the action of the water in the first two penstocks, it does not appear that there would be any serious difficulties in handling the wheels with the ordinary gates on the pressure side. There are certain objections to the butterfly valve arrangement, principally owing to the fact that the valves are large and heavy, which interferes with their easy handling by the governor. The gates on these two wheels are controlled by a Lombard governor, having its operating cylinder fixed to the face of the case. The governing has been quite satisfactory. Of course, wheels with gates of this type would not be efficient except at full opening of the gate.

As the throttling of the discharge in the draught tube raises the pressure, cutting down the head, the use of water at part-gate is necessarily quite inefficient. That is not, however, an important point in the case of a plant taking its water directly from the flow of the river without any attempt at pondage. A certain part of the flow of the stream must be appropriated to each unit, and the fact that during the comparatively few hours of low load the units may not take all the water appropriated to them is not important, as the water simply flows down the river when not used. Especially is this unimportant in the case of a small number of the first units in the power house. The experience with the penstocks, however, has been so satisfactory that a third wheel of the Francis type is being installed with the movable guide type of gate. Otherwise the third wheel is similar to the first two.

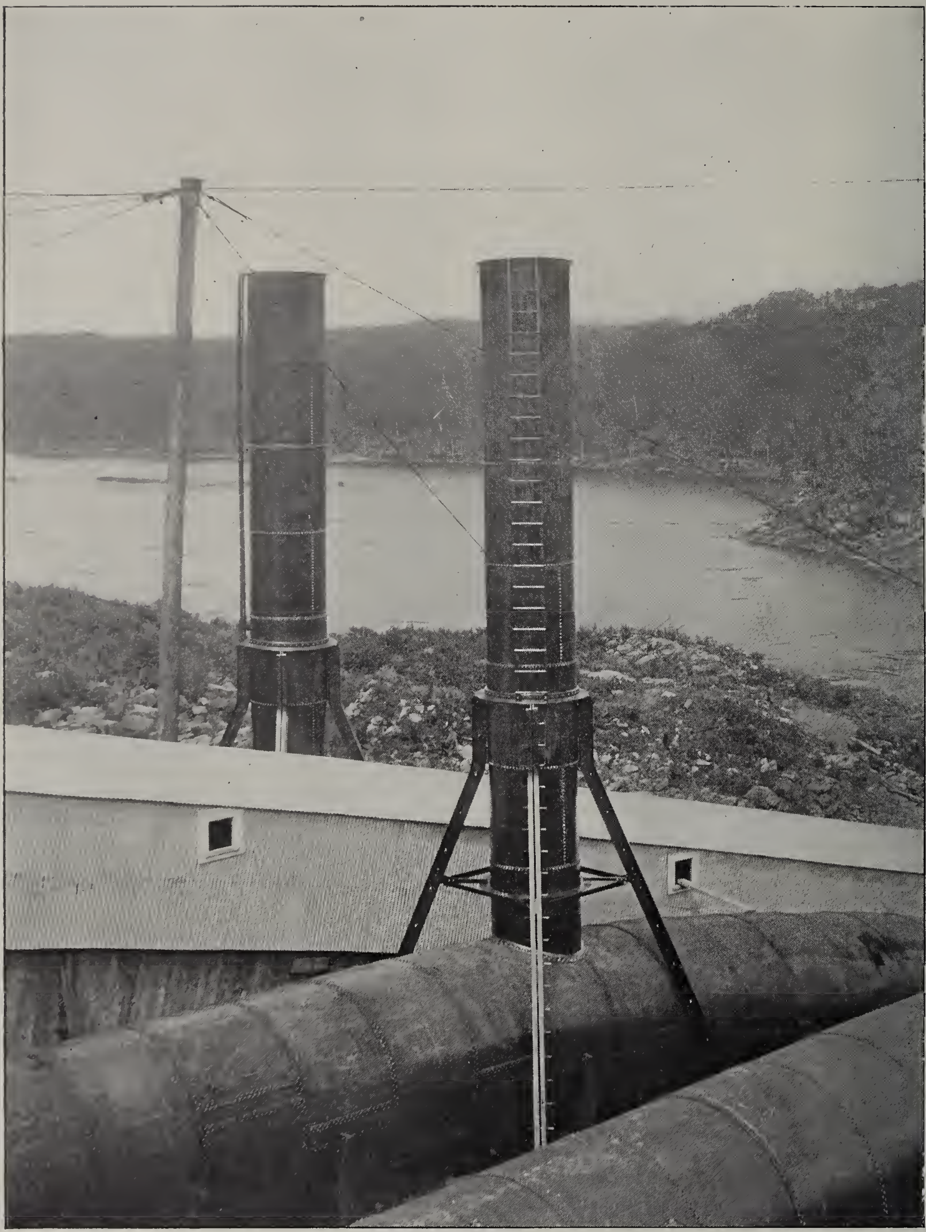
As it was found desirable to use the space underneath the switchboard gallery for a larger number of large oil switches than was first calculated upon, it was desirable to have a continuous space underneath this gallery, not cut off by penstock pipes; hence it was decided to lower the penstock pipes at this point and to provide a switch room underneath the switchboard gallery. For this and other reasons it was decided to make the additional units of the spiral case type, receiving water on the lower quarter and discharging outward through quarter turns and two draught tubes, as shown in the plan on page 194.

Six thousand horse-power are now being delivered in Montreal. A second transmission line of 10,000 H. P. capacity is now under construction, and the amount of power delivered is to be greatly increased within the next few months. Other large units of power are arranged for at Shawinigan Falls. It has, therefore, been decided to increase the size of the next water-wheels installed to 10,000 H. P., each driving a 6600 KW generator. Unit No. 4 of that capacity has been contracted for.

The placing of the wheels and generators with the shafts at right angles to their present position, bringing the generator in one line facing the switchboard gallery, was carefully considered. Such an arrangement would make the connections from the generators to the switches simpler, and would have brought the generators more directly under the eye of the switchboard attendant. The increased efficiency due to the direct flow of the water to the wheel obtained by the present arrangement is the more important consideration.

The power house stands on solid rock excavated to a depth of 15 to 20 feet to get the tailraces down to the proper depth. The rock in that vicinity is solid, unstratified granite which does not require protection in the bottom of the tailraces. On the rock itself walls about six feet thick are built up, separating the tailraces; arches of concrete are turned over the tailraces, about four feet thick at the crown.

On the basement floor concrete foundations are built for the generators and water-wheels. These foundations also carry the floor beams, on which a floor



SOME OF THE VENT PIPES IN THE PENSTOCKS

of concrete is laid. The concrete side walls, as previously stated, are carried up to the window sills. On top of these concrete walls are built the brick walls of the power house, with pilasters supporting 24-inch beams carrying the crane rails, on which is a travelling crane of 50 tons capacity, running the entire length of the power house. The roof consists of steel trusses and 3-inch tongued and grooved plank laid directly on the trusses and covered with slate.

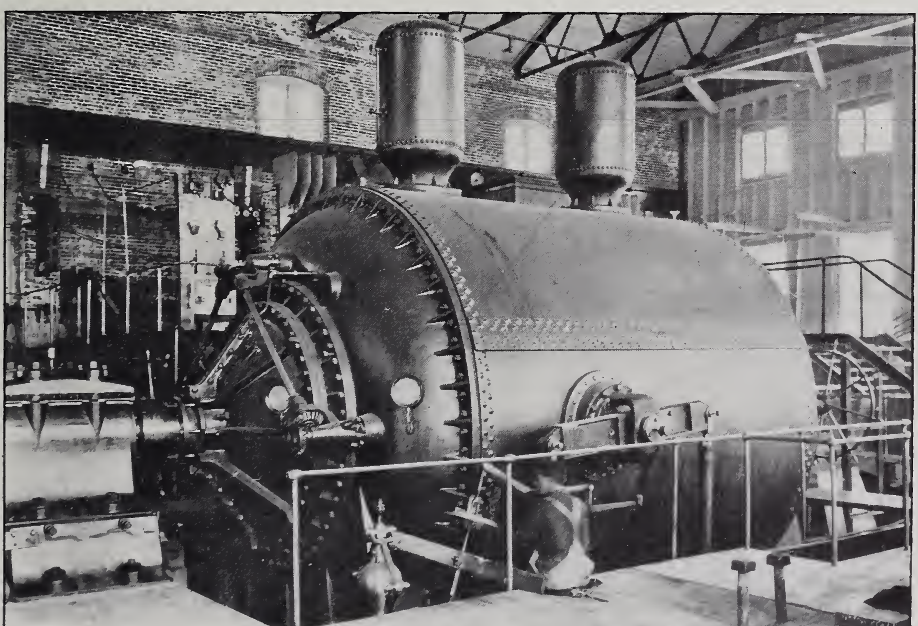
The first work done by the contractors on commencing construction in May of 1899 was to build a railway five miles to a connection with the Lower Laurentian Railway. Notwithstanding the lack of transportation facilities at the commencement of the work, this was pushed with such vigour that the Pittsburgh Reduction Co. were enabled to to begin making aluminium late in 1901.

The following year the Belgo-Canadian Pulp Company started their pulp mill, which is operated by water taken from the upper lake, about half a mile above the canal, and discharged into the Shawinigan River,—a small stream flowing into the lower lake. A plant for the manufacture of calcium carbide and another for the manufacture of ferro-manganese taking current from the main power house are now in operation.

Considerable quantities of flax are grown in the vicinity of Shawinigan, and a linen mill is about to be built there. Shawinigan Falls is now a city of 3000 people. Through the efforts of some of the men connected with the Shawinigan Water & Power Company the Great Northern Railway of Canada was organised, and purchased the Lower Laurentian road, which had its eastern terminal at Quebec. The line was extended to a connection with the Canada-Atlantic Railway near Ottawa, with a branch to Montreal, thus opening up the shortest of all the routes from the Northern Great Lakes to the seaboard. Three Rivers, now a port at which any ocean-going vessel can land freight, is only 17 miles from Shawinigan. Surveys for a direct line of railroad are at present in progress.

Shawinigan, four years ago accessible only by canoe, is now in possession of excellent transportation facilities. Nature lovers will be pleased to know that all this development has been effected without in any degree detracting from the beauty of the falls themselves. The forest primeval still clothes the banks of the falls, and the taking of water sufficient for 25,000 H. P. has not made a perceptible diminution of the amount of water flowing over them.

Chutes de Shawinigan are still one of the most beautiful of natural spectacles.



ONE OF THE 6000 H. P. WATER WHEELS MADE BY MESSRS. ESCHER, WYSS & CO., ZÜRICH, SWITZERLAND, AND THE I. P. MORRIS CO., PHILADELPHIA

ELECTRIC POWER FROM SHAWINIGAN FALLS, CANADA

PART II.—THE ELECTRIC TRANSMISSION PLANT

By Ralph D. Mershon

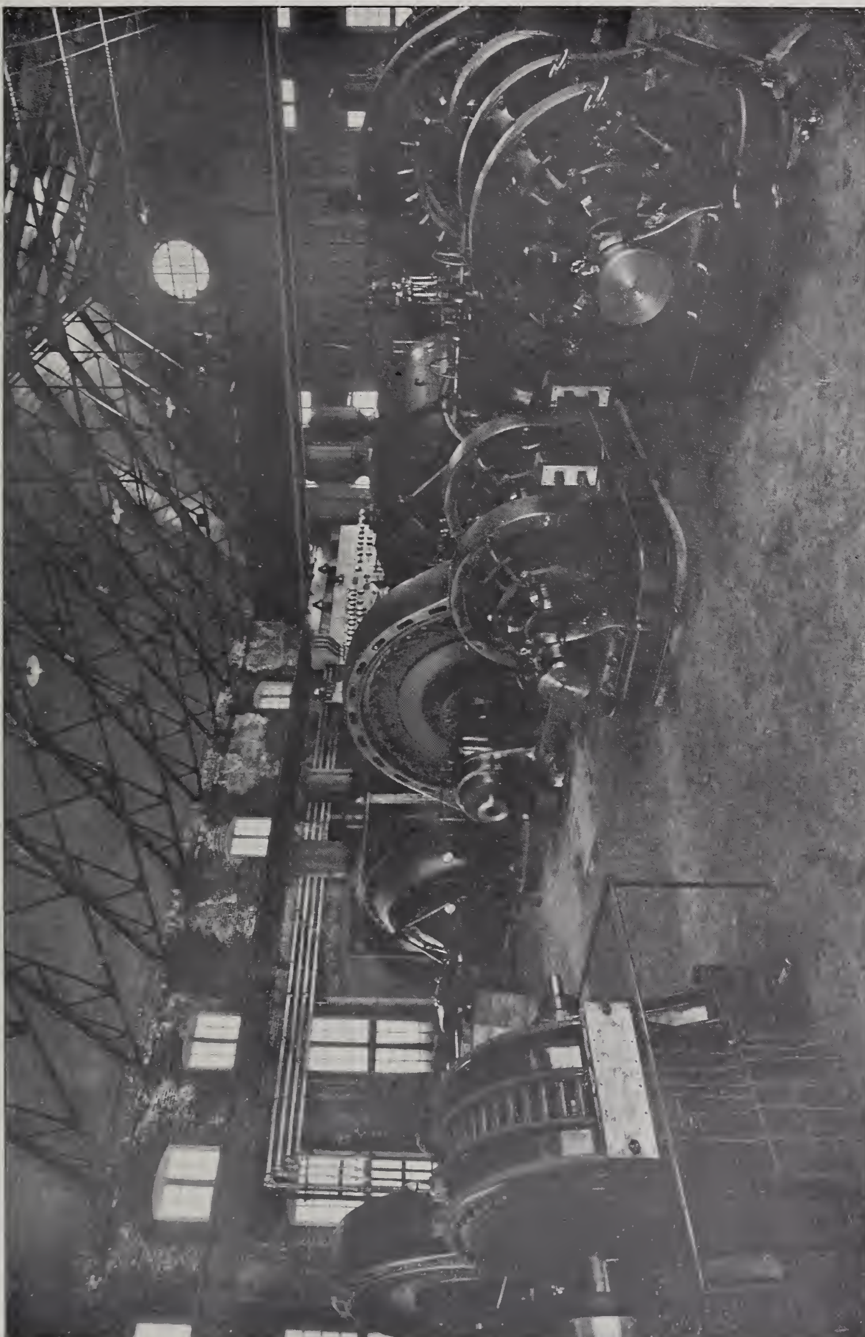
A MAIN LINE POLE

THE future industrial development of Canada will undoubtedly be closely associated with the utilisation of her numerous waterfalls. Primarily, this will be due to the demand which industrial processes always make for cheap power; but as a secondary effect the development of these natural sources, and the consequent cheap power, will, in itself, accelerate and stimulate industrial progress.

The availability of cheap power cannot fail to give Canada an advantage in industrial competition, and this advantage will be more marked as, in the course of time, the keenness of competition approaches that point where every advantageous circumstance must be closely sought for and diligently utilised. Large amounts of the power made available by the exploitation of these natural sources will be used at or near the point of generation, but in many cases it will be preferable to transmit the energy to other points more or less distant from the generating centre.

Water-power development along industrial lines and on a large scale has already begun in Canada, and one of the pioneer plants in this field is that of the Shawinigan Water & Power Company. This company have undertaken the development of Shawinigan Falls, situated on the St. Maurice River, not far from where it empties into the St. Lawrence, and approximately half way between Montreal and Quebec. The hydraulic features of the work have been treated of in the preceding article by Mr. W. C. Johnson.

The development of the falls has been laid out to admit of supplying consumers with either hydraulic power, to be utilised on water-wheels owned by the consumer, or with electric power. For the latter purpose an electric generating station was designed, and the first portion of it was completed about three years ago. Since then, and recently, there has been added to the electric equipment a transmission system for delivering power in Montreal, at a distance of a little more than 84 miles from the power station. This transmission plant was installed in consequence of a contract made for the sale of power to the Lachine Rapids Hydraulic & Land Company, operating a generating station at Lachine Rapids, about eight miles from Montreal, and delivering and distributing current for lighting and power in Montreal in competition with the Montreal Light, Heat & Power Company. The Lachine Company were compelled to purchase this additional power by reason of the fact that the limit of the capacity of their generating station had been reached. Since the time when the delivery of power was begun under this contract the Lachine



THE GENERATING STATION AT SHAWINIGAN FALLS, SHOWING THE RELATIVE LOCATIONS OF GENERATORS, EXCITERS AND SWITCHBOARD

A TEMPORARY LINE ON ICE OVER OTTAWA RIVER

Company has been absorbed by the Light, Heat & Power Company, and the power is now delivered to the latter company.

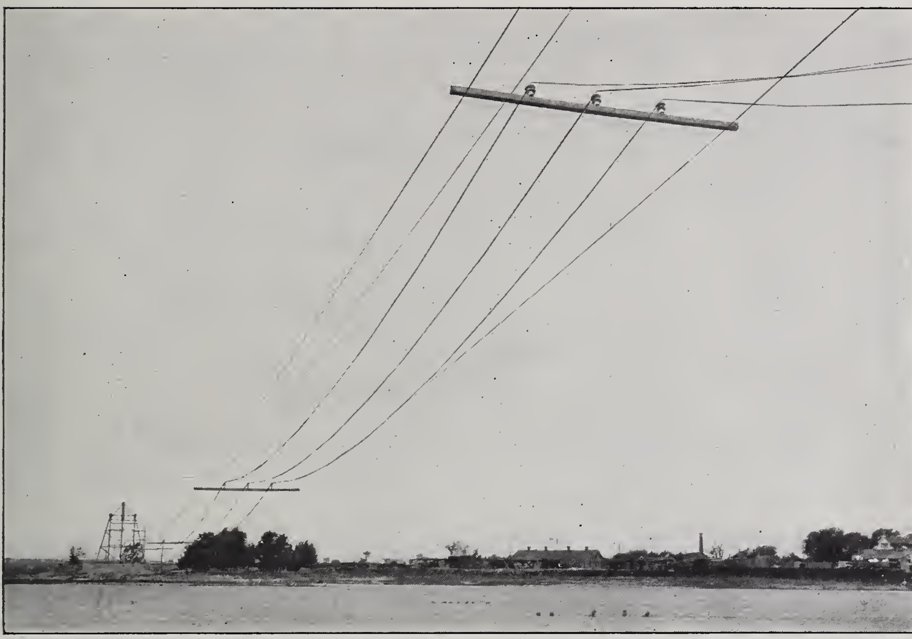
The power contract was made in May, 1902, with the condition that the delivery of the first block of power,—2000 horse-power,—was to commence on January 1, 1903. Work was begun on the plant about June 1, 1902, and the transmission of power to Montreal began on February 3, 1903. The total amount of power being delivered at the present time is something over 6000 horse-power.

The generating equipment at Shawinigan Falls was first put in with reference, chiefly, to the probable requirements of the large local customers of the Shawinigan Company, all of whom would use the power for industrial purposes, and not with any special reference to long-distance transmission, which, at the time, was looked upon as a future probability more or less remote. The generating units installed for this purpose are three in number, and consist each of a 3750 KW quarter-phase, 2200-volt, 30-cycle generator, direct-connected to a horizontal shaft turbine. As the contract made by the company for power in Montreal necessitated the delivery of current at 60 cycles, and as it would have been impossible in the time allotted for the completion of the transmission system and the delivery of the first block of power to procure 60-cycle generators, it was decided to transmit at 30 cycles and convert to 60 cycles in Montreal by means of synchronous motor-generators.

The view of the interior of the generator room at Shawinigan Falls shows the relative position of the generating units and the switchboard. The switchboard is located on a gallery at one side of the room over the penstocks. The space below this gallery, such as is not taken up by the penstocks, is occupied by the main switching apparatus and cables. The cables between the switchboard apparatus and the generators are all in ducts in the basement below the generator room floor. The switchboard is one of the usual marble panel type, on which are mounted the various instruments, ammeters, wattmeters, voltmeters, etc., and the handles, indicators, time-limit overload relays, etc., controlling the electrically-operated oil switches for generators and transformers.

Each generator has one electrically-operated oil switch, but may be thrown on to either of the two sets of bus bars which are provided so that the local load and the transmission load may be kept separate. This is accomplished by means of selector switches of the blade

type arranged so as to be electrically interlocking with the main generator switch; that is, the main generator switch cannot be thrown unless the selector switches are all closed, and closed in the manner which will throw all the leads they control on to the same set of bus bars. Conversely the selector switches cannot be thrown unless the main oil switch is open. The diagram of connections of the selector switches on page shows 215 how this is done. From the transformer switches the cables pass to the transformer house through



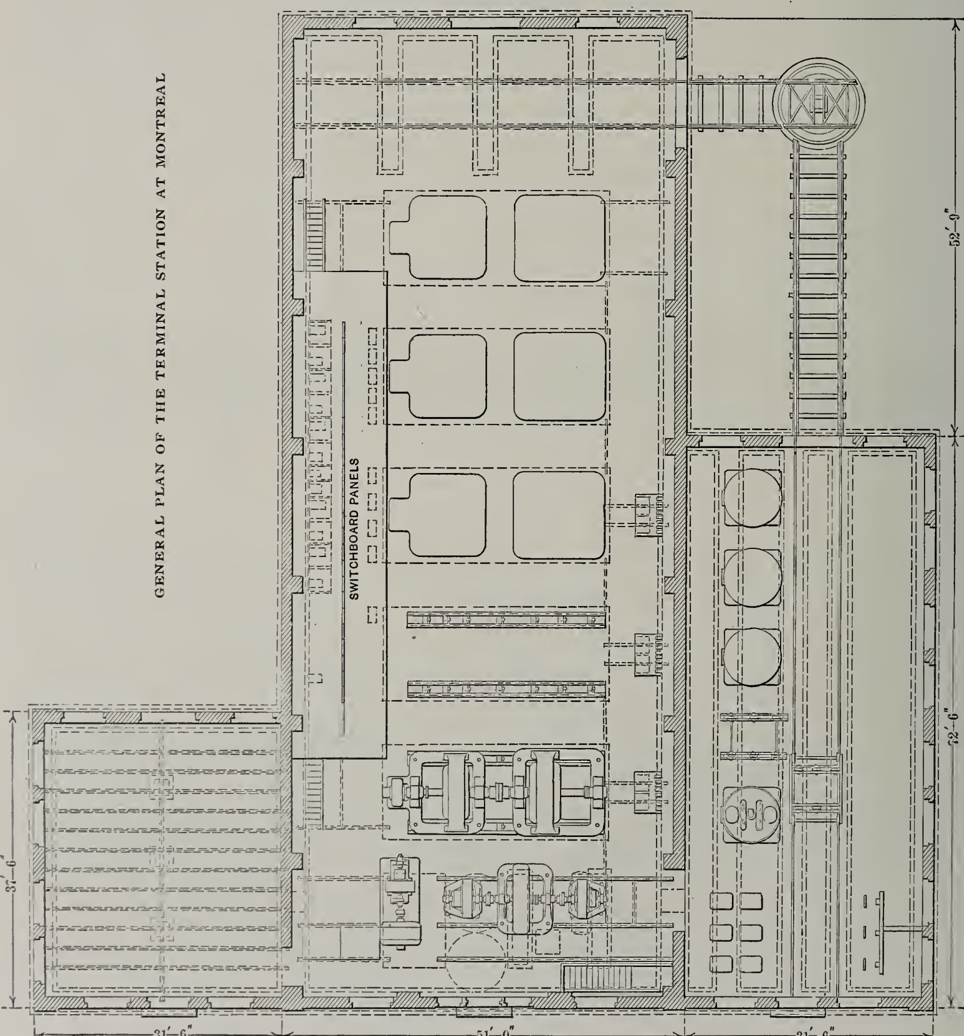
AN 1800-FOOT TEMPORARY SPAN OVER OTTAWA RIVER

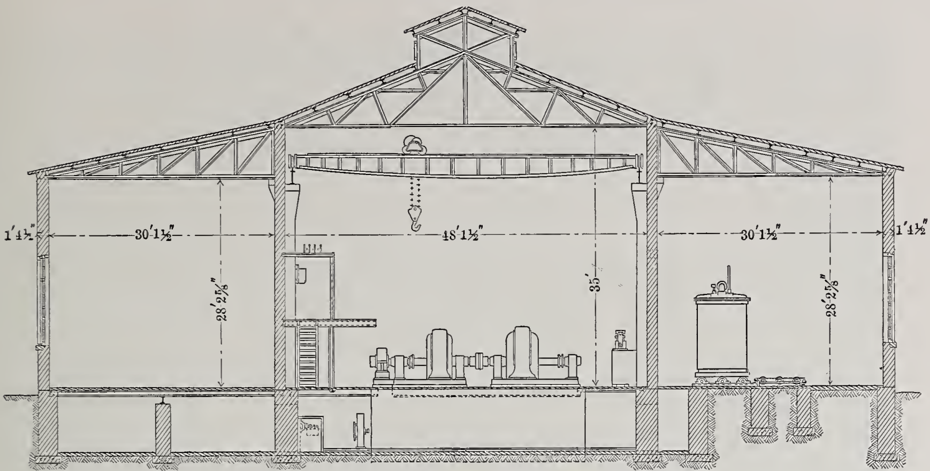
BRIDGE LINE REPLACING THE 1800-FOOT SPAN SHOWN ABOVE

ducts. Throughout the power plant the cables, where not in fireproof ducts, are, wherever it is possible, separated from one another by fireproof barriers, so that an arc in one set of cables cannot damage adjacent cables.

The step-up transformer house was added to the generating station at the time of installing the transmission. The relative location of these two buildings is shown by the plan view of them. In the transformer house are located the step-up transformers for the transmission and for the local power distribution, and all high-tension wiring, lightning arresters, ground detectors, etc. At the present time six step-up transformers are installed, two pairs in operation and one pair as a relay. They are of the oil-insulated type, and the rated capacity of each transformer is 1110 KW, but it can safely carry a large overload. The transformers are interconnected in pairs for transforming from 2200 volts quarter-phase to three-phase 50,000 volts. When it is desirable, they may be operated at 56,000 volts. The transformers are all alike, so that any one can be used for either a 100 per cent. or an 87 per cent. transformer. The

GENERAL PLAN OF THE TERMINAL STATION AT MONTREAL



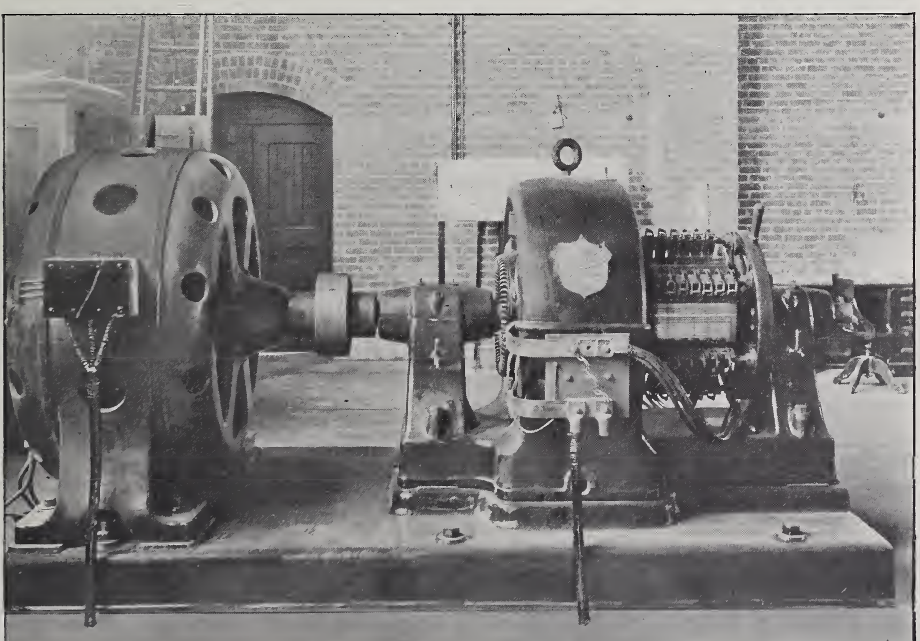


CROSS SECTION OF THE MONTREAL TERMINAL STATION

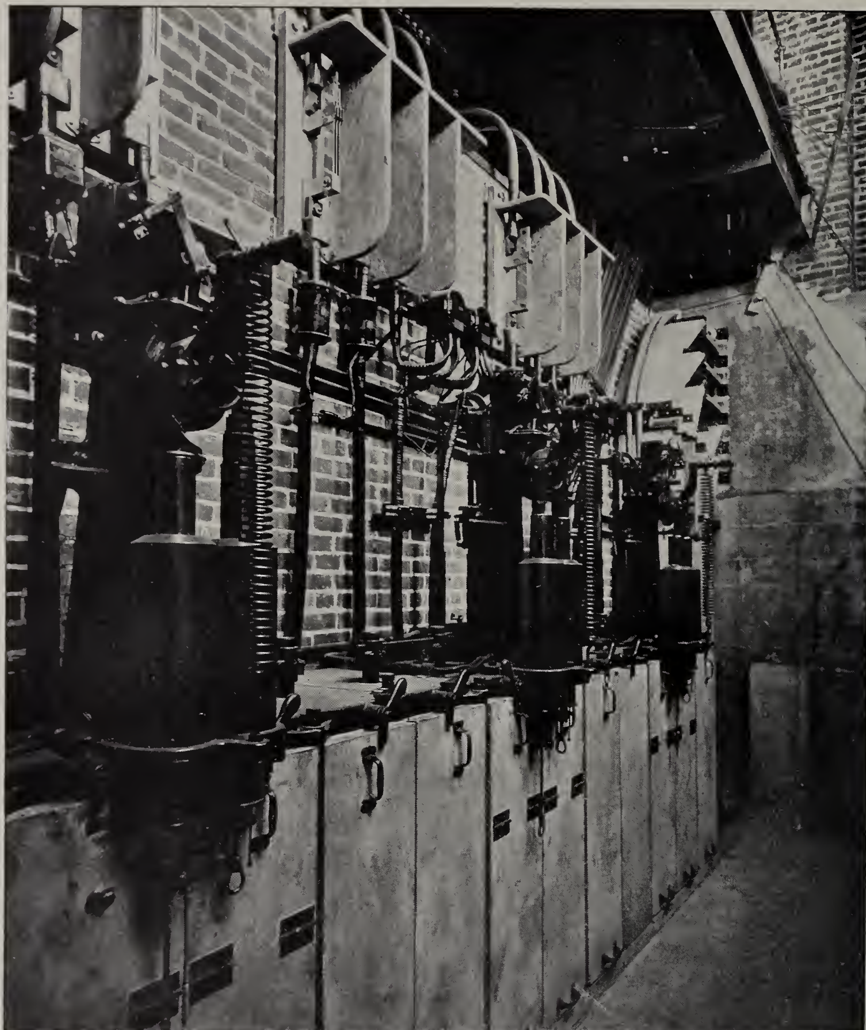
method of connection of these transformers and of substituting the relay pair for one of the working pairs is shown in the diagram of connections on page 212.

The transformers are water-cooled, the cooling water circulating through spiral brass tubes immersed in the oil near the top of the case. The transformer cases are of boiler iron, and are designed so as to realise a device intended as a protection against possible explosion or fire in the transformer oil. This device may be described as follows:

To the centre of the lid of each transformer tank is connected a large pipe



AN INDUCTION MOTOR-GENERATOR SET FOR STARTING THE SYNCHRONOUS FREQUENCY CHANGERS IN THE TERMINAL STATION AT MONTREAL



ELECTRICALLY OPERATED OIL SWITCHES AND CUT-OUT SWITCHES IN THE SHAWINIGAN POWER HOUSE

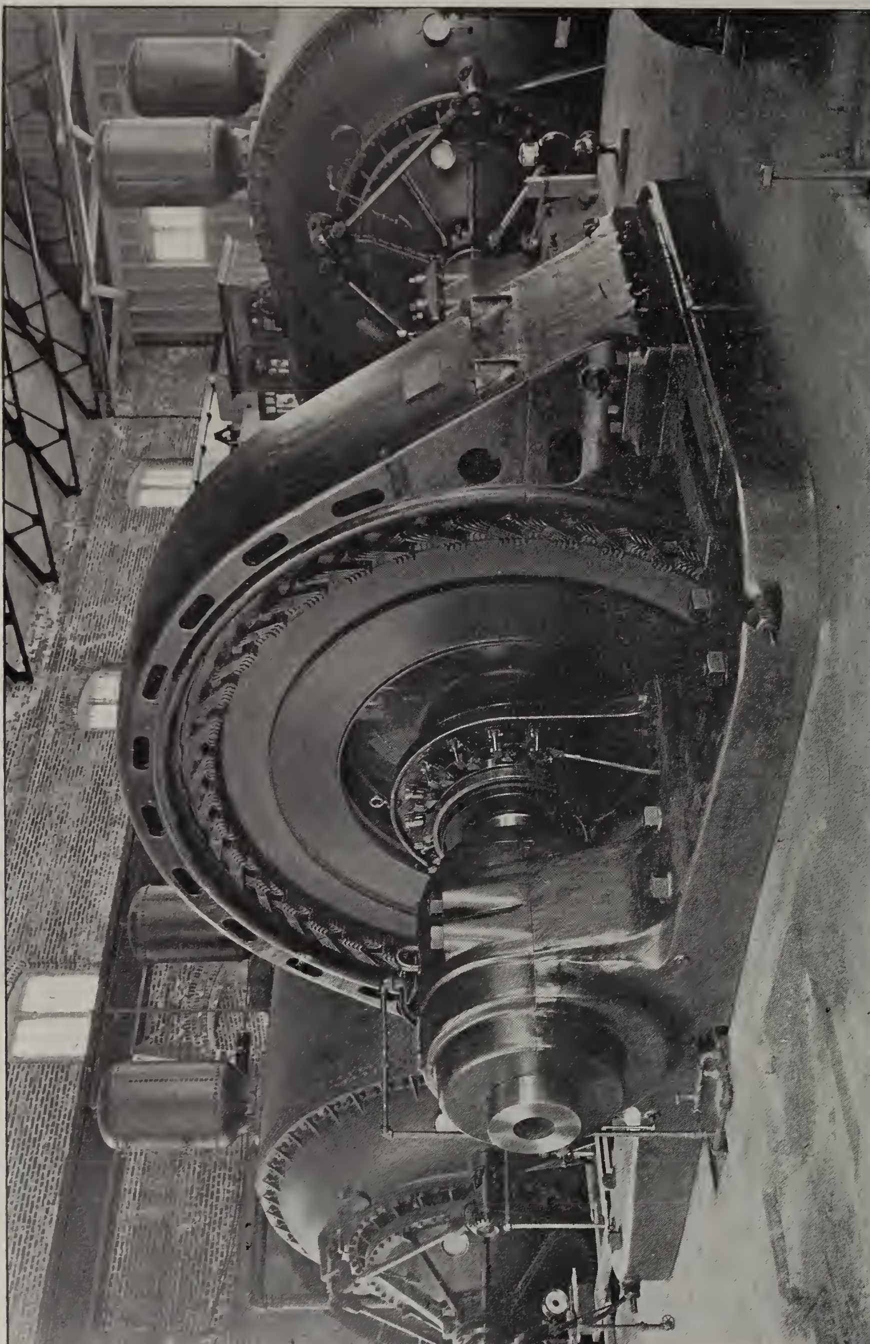
leading to the sewer. At the bottom of the tank is another pipe connected to the source of water supply and closed by two valves in series, between which is a small drip cock to prevent the possibility of water entering the transformer tank through a leaky valve. The lid of the tank is fitted carefully to the tank itself with gaskets, and all conductors passing through the lid are brought out through stuffing boxes so that the tank is practically air-tight, except as regards the vent from the middle of the lid through the pipe into the sewer. The tank and all its fittings are built to stand the maximum pressure which could be generated by the ignition of any mixture of air and oil vapour which might collect over the surface of the oil. The tank itself is, therefore, amply strong enough to stand the force of an explosion, and, in addition, there is the vent from the top to the sewer to relieve and keep down the pressure of any explosion which might occur.

If, after trouble in the transformer,

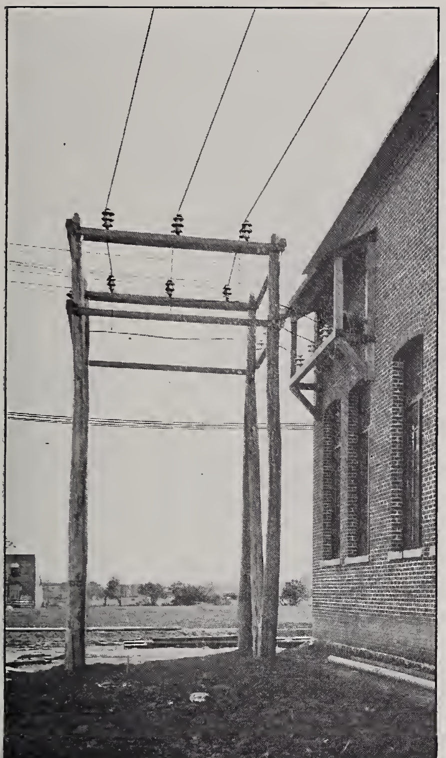
ELECTRICALLY OPERATED OIL SWITCHES IN THE MONTREAL TERMINAL STATION

the oil should continue to burn, making it desirable to get the oil out of the tank, the water valves at the bottom of the tank may be opened, thus admitting water to the tank and forcing the oil out of the top into the sewer. This is a much safer way of emptying the tank than by the usual means of a valve at the bottom, since in the latter case air must be drawn into the tank as the oil passes out, making possible the formation of an explosive mixture and risking the danger of an explosion. Even if the oil were not burning, there is more or less danger in drawing it out of the bottom of the tank, since the explosive mixture formed thereby would be ignited by any smouldering bits of insulation which might be present.

The use of the water would not be resorted to except in an extremity, but it is believed to furnish in case of such extremity a safeguard much more effective than anything else which has been proposed. If the water be used, it will not necessarily do any great damage to



ONE OF THE GENERATORS AT SHAWINIGAN FALLS



ENTERING THE TERMINAL STATION AT MONTREAL

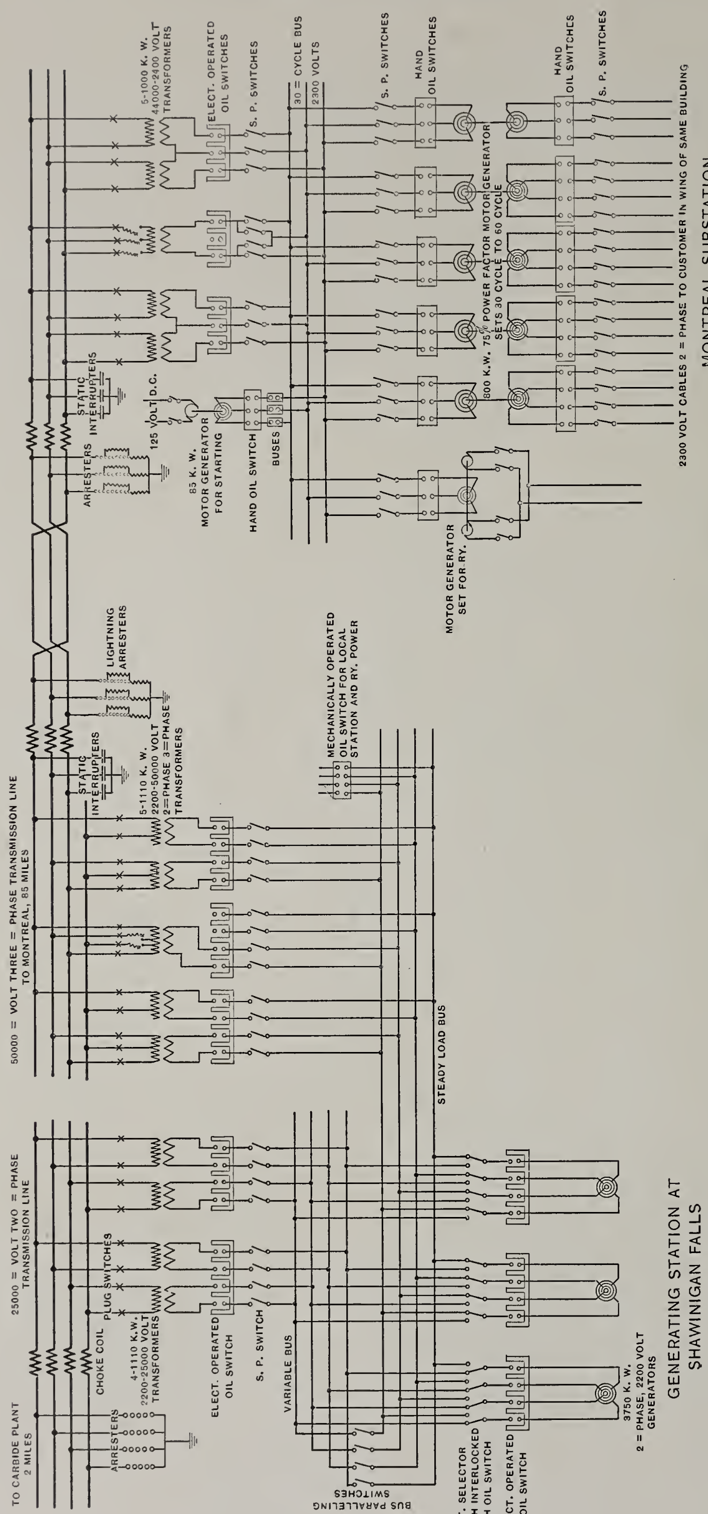
There is no crane in the transformer room. This leaves all the space above the transformers available for high-tension wiring, in which bare conductors are employed throughout. As a substitute for the crane a truck is provided by means of which any transformer may be moved to a portion of the building where a chain block is available for removing the transformer from the case. The arrangements for handling the transformers in this manner are as follows:—

Each transformer tank rests upon a cast iron base, the plan of which is approximately square. On the bottom of this base are cast two rails, which do not, however, extend below the bottom edges of the base itself. Thus, if the base were turned upside down, there would be seen two parallel rails like a short portion of railway track, the tops of the rails being flush with the edge of the base. When the transformers are in place on their foundations the rails mentioned above rest on two lines of flanged wheels, the wheels being held and supported upon the masonry foun-

the transformer, especially if it be not allowed to remain long in the transformer tank. An oil-soaked transformer will not readily take up water, and such water as it does take up can be dried out. The transformer in most cases will have to be dismantled for repairs, and the dismantling will make the drying out more easily and quickly accomplished. With the transformers installed in the manner described, it is believed that no serious damage could result from either an explosion or fire.

In addition to the piping above mentioned there is also the usual piping for emptying or filling the tank with oil under other than emergency conditions. A suitable motor-driven oil pump is provided for this purpose. An oil tank is also provided for the storage of spare oil, and into this any transformer can be emptied when it is desired to do so temporarily.

A MAIN LINE INSULATOR AND PORTION OF LINE CABLE

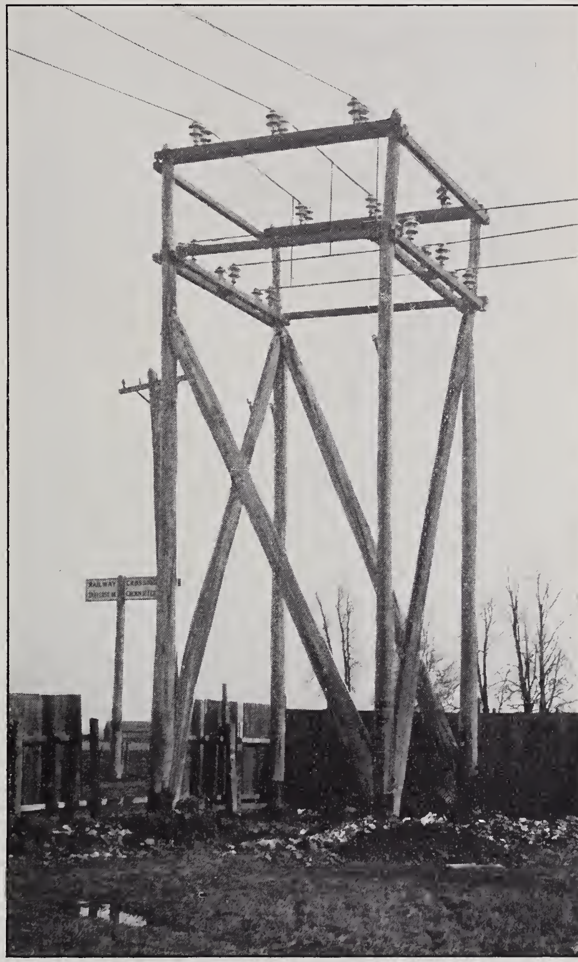


GENEEAL WIRING DIAGRAM OF THE SHAWINIGAN FALLS TRANSMISSION

dation in such a way that they are free to rotate, but are fixed in position. The result is that the transformer can be rolled back and forth on its mounting as though a portion of track were rolled back and forth upon the wheels of an upturned car.

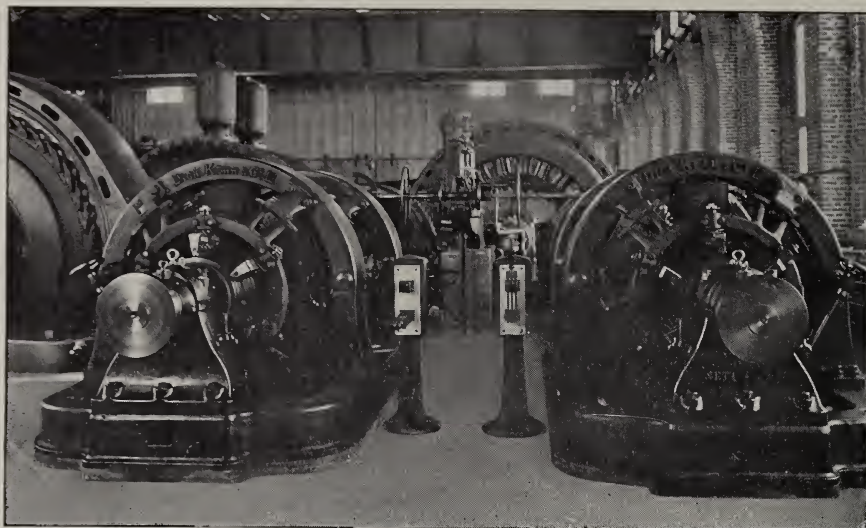
Parallel to the row of transformers and flush with the concrete floor of the station is a track on which runs a steel truck. This steel truck has upon it a mounting of wheels similar to that on which the transformer normally rests, so that the truck may be rolled up in front of a transformer until the mounting of the truck matches with that on which the transformer rests and the transformer rolled off its mounting on to the mounting on the truck. The truck can then be run to the end of the building and use made of a chain block mounted on a traveller moving at right angles to the track. This method of handling the transformers will be easily understood by reference to the illustration on page 216, showing some of the transformers and the truck in ront of one of them. The arrangement is much cheaper than a crane, and, what is more to the point, it leaves the space above the transformers free for the high-tension wires.

From the high-tension terminals of the transformers the current passes to the high-tension bus bars through long-break knife switches, which may be operated by a pole from the floor and are intended as a means of connecting or disconnecting the transformers from the bus bars under conditions of no load. These are the only high-tension switching devices employed. These switches and the high-tension wiring are mounted on line insulators supported upon a suitable wooden rack suspended from the roof trusses of the station. From the high-tension bus bars the high-tension wires pass through static interrupters, consisting of oil-insulated condensers and choke coils, and then out of the building through large sewer tile set in the wall and closed by glass plates pierced in the centre by holes for the line conductor.

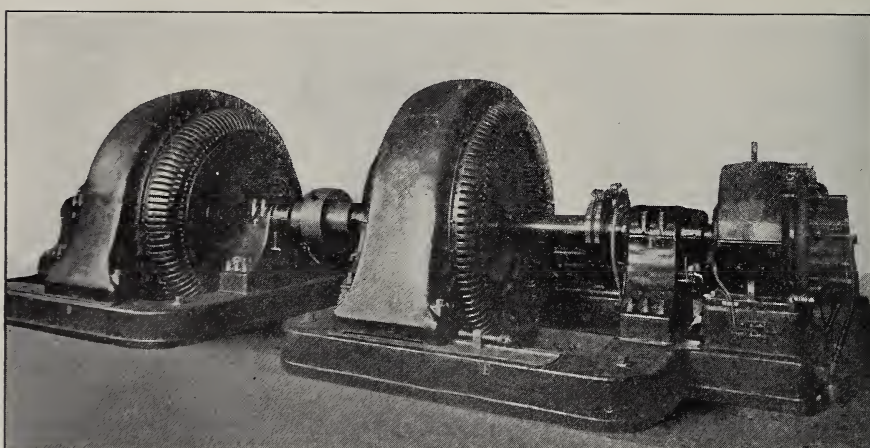


A RIGHT-ANGLE TURN IN THE TRANSMISSION LINE

At a point just before the line passes out of the building are connected the lightning arresters, consisting of three slabs of marble, one for each line wire,



EXCITERS IN THE SHAWINIGAN FALLS POWER HOUSE



SYNCHRONOUS MOTOR-GENERATOR FREQUENCY CHANGERS IN THE MONTREAL TERMINAL STATION

on which are mounted low equivalent, non-arcing-metal lightning arresters. Between the static interrupters and the lightning arresters are connected two ground detectors, one from the middle wire to one outside wire, and the other from the middle wire to the other outside wire. The ground detectors are not directly connected to the line conductors, but receive current through the medium of sleeve condensers, one on each line wire.

The total length of the transmission line from the generating station at Shawinigan Falls to the terminal station in Montreal is 84.3 miles. It consists of three aluminium cables, each composed of seven No. 7 aluminium wires. The total drop in the transmission line when 8000 horse power are being delivered to the customers' bus bars in Montreal is, at unity power factor, about 18 per cent. of the delivered voltage, requiring about 50,000 volts at the generating station. By operating at a higher drop, considerably more power may be transmitted

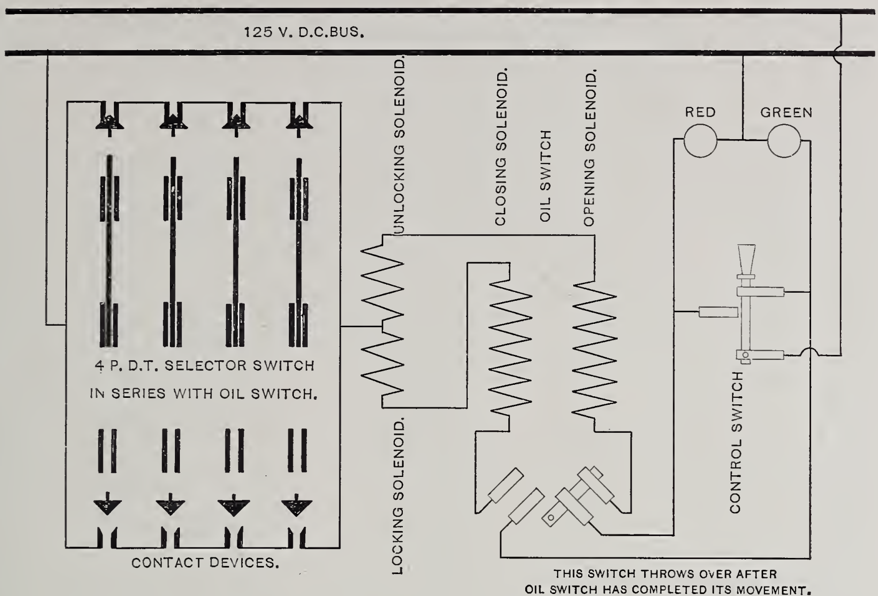
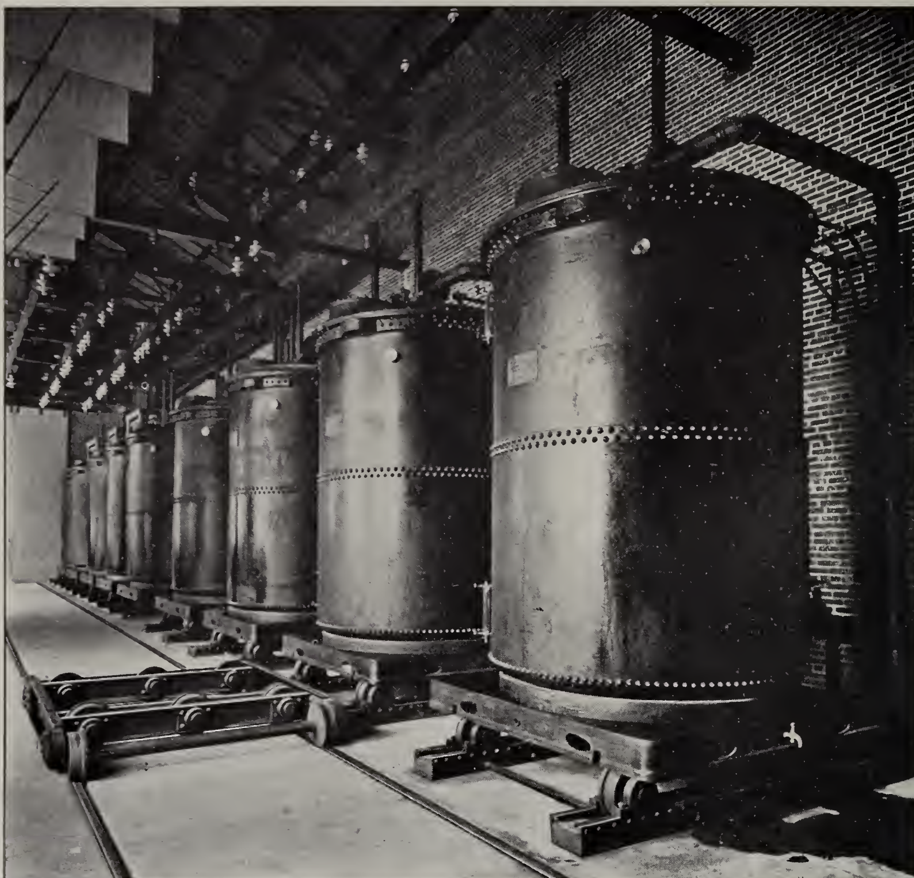


DIAGRAM OF SELECTOR SWITCH CONNECTIONS. THE CIRCUIT IS CLOSED THROUGH CONTACT DEVICES ONLY AFTER ALL SWITCH BLADES ARE CLOSED AND IN POSITION TO BE LOCKED. THE CIRCUIT IS BROKEN THROUGH CONTACT DEVICES ONLY AFTER THE OIL SWITCH HAS BEEN OPENED, UNLOCKING THE SWITCH BLADES AND BEFORE ANY BLADE IS WITHDRAWN FROM CLIPS. THE OIL SWITCH IS SHOWN CLOSED

THE TERMINAL STATION AT MONTREAL



STEP-UP TRANSFORMERS AT SHAWINIGAN FALLS FOR BOTH LOCAL AND LONG-DISTANCE SERVICE. THE ILLUSTRATION EXPLAINS HOW THE TRANSFORMERS ARE HANDLED

over the line, and it is possible to do this with the present installation, since, as mentioned elsewhere, the step-up transformers are capable of operating at considerably over their rated voltage.

The three line cables are arranged in an equilateral triangle, the distance from centre to centre of the cables being 60 inches. One of the cables is carried on top of the pole and the other two are at the ends of a cross-arm. The insulators were specially designed by the writer for this plant and this voltage. Before shipment all of them were given a salt-water test of 100,000 volts for one minute. They are of porcelain, and are in three parts, held together by Portland cement. The poles are of cedar, and are set generally 100 feet apart, although where necessary the span has been increased to 200 feet. Each pole is bored in the top for the top pin, and the top of the pole is surrounded by an iron band driven tightly on to prevent splitting. The cross-arms are of southern pine, treated by dipping in a hot, weatherproof, and preserving mixture. The pins are of hickory, treated by boiling in stearic acid.

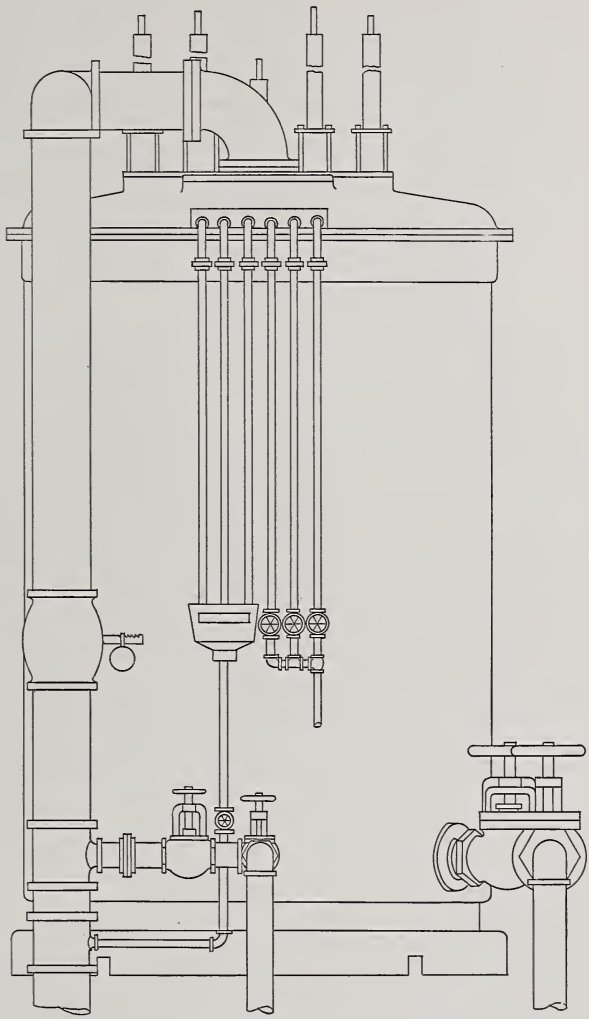
At the point where the line crosses the Ottawa River there were, at first, two long spans, one 1180 feet and the other 1850 feet in length. A railway bridge has been built at this point on which the transmission line has been transferred, but for some time the line crossed the river by way of these spans put up in a temporary manner on wooden

towers. The spans were made by fastening to two supporting cables, 20 feet apart, cross-arms at intervals of about 200 feet, on which were supported line insulators and the line conductors. Each supporting cable was 1 inch in diameter and of plow steel. There was a third cable above the other two, on which, by means of a traveller and cradle, linemen could go out on the span for the purpose of making repairs.

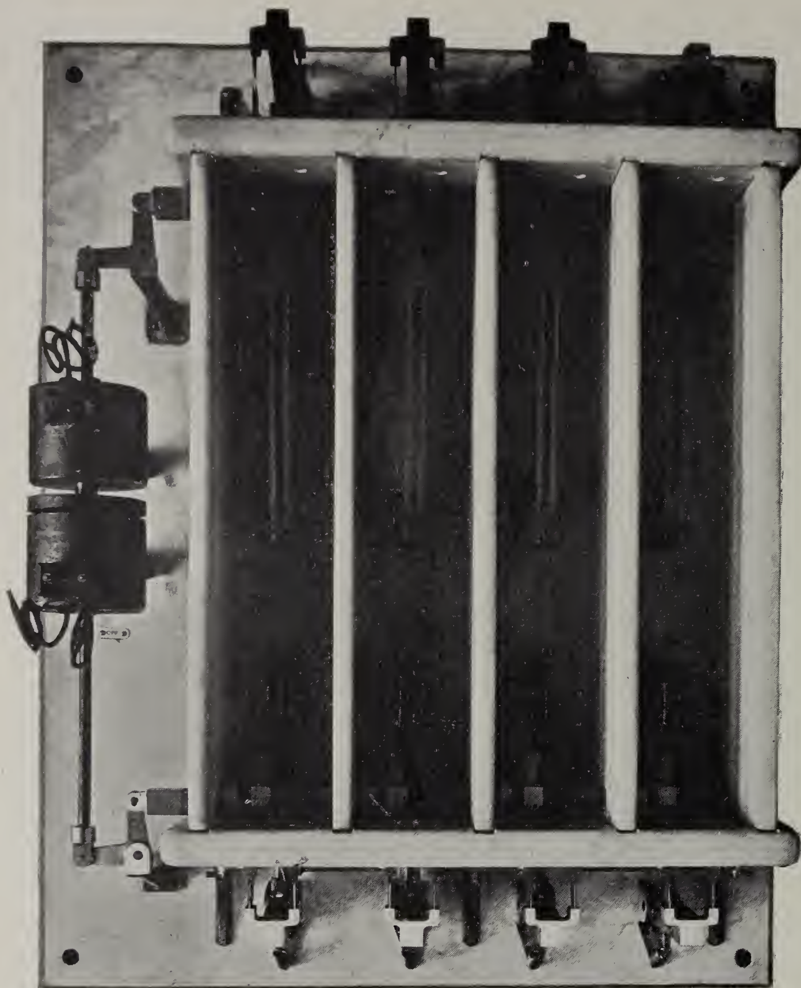
These spans were not completed at the same time as the rest of the plant, and in order to get the plant in operation as soon as possible a pole line was constructed on the ice, which at the time covered the Ottawa River, the poles being fastened to cross pieces frozen to the ice by piling wet snow on them. The line operated in this way for several months before being transferred to the long spans.

The main transmission line is transposed at two points at approximately one-third and two-thirds of the total distance. The pole line also carries upon it a telephone line, which is transposed wherever necessary. It is the present intention of the company to install within the year a second transmission line between Shawinigan Falls and Montreal in order to provide for an increase in the capacity of the transmission plant and insure continuity of service.

Although the transmission was installed with especial reference to the delivery of power in Montreal, it is intended to supply power as well at points along the line. The branch line has already been built and lately put into operation. It branches off from the main line approximately half way between Shawinigan Falls and Montreal at the town of Joliette. At this point a transformer house is installed, containing transformers stepping down from the voltage of the main line to 12,000 volts. At this latter voltage 500 H. P. are transmitted to the town of Sorel, where it is stepped down to 2200 volts for lighting and power service. The transformation to 12,000 volts is made largely because of two submarine cables forming a part of this branch transmission line and the undesirability, under the conditions obtaining, of using the higher voltage in the cables. One of



THE TRANSFORMER PIPING



INTERLOCKING SELECTOR SWITCH IN THE POWER HOUSE AT SHAWINIGAN FALLS

these cables runs underneath the St. Lawrence River and the other underneath the Richelieu River.

The terminal station is situated some distance from the centre of the city of Montreal. It consists of a brick and steel structure divided into three rooms. The main or middle room contains the motor-generator frequency-changers and the switchboard apparatus for controlling them and for controlling the step down transformers. At one side of this room is the transformer room, and on the other side is a room for the distribution switchboard of the Lachine Rapids Hydraulic & Land Company, now operated by the Montreal Light, Heat & Power Company.

The transmission line enters the terminal station in a manner similar to the one in which it leaves the transformer room at the generating station. After entering the step-down transformer room it passes through lightning arresters and static interrupters and thence to the step-down transformers through overhead wiring and switches supported on racks in a manner similar to that described for the step-up transformers. The step-down transformers are similar

to the step-up transformers, except that their capacity is 1000 KW each instead of 1110 KW, and they are wound for transforming from 44,000 to 2400 volts. There are at present five of them, four being connected in *V* for transforming from three-phase to three-phase, the fifth being held as a relay. Later a second relay transformer will be installed, the pair being held in reserve, in which case all transformers will be interconnected in pairs for transforming from three-phase to three-phase. The piping provided for emptying and for cooling the step-down transformers is similar to that described for the step-up transformers, as are also the means provided for handling them and the protection against damage due to fire in any of them. From the step-down transformers the current goes to the synchronous frequency changers, and from them, at 60 cycles, to the distributing bus bars in the previously mentioned distributing room of the Montreal Light, Heat & Power Company.

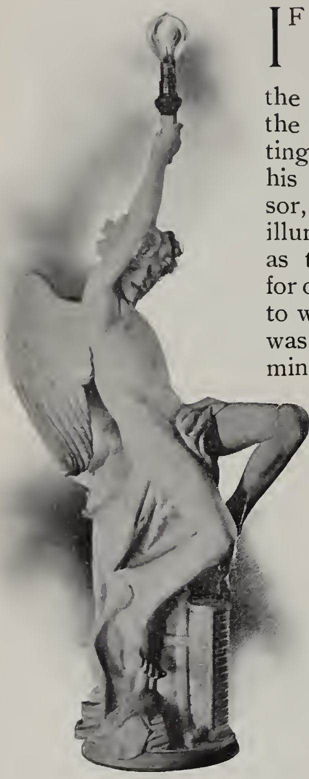
The frequency changing sets are at present five in number. Their nominal capacity is that for an output of 800 KW at a power factor of 75 per cent., but they have an overload capacity considerably in excess of this. Originally all of them consisted each of a three-phase, 30-cycle, 2400-volt synchronous motor, direct-connected to a three-phase, 2400-volt, 60-cycle generator; but some of the generators have since been changed to quarter-phase in order to accommodate them to the system of the Montreal Light, Heat & Power Company. Mounted on the shaft of the generator is the exciter for the whole set, which, when the unit is being started, is used to bring it up to speed, its series field being reversed for this purpose. The current for starting is derived from an auxiliary set intended for starting purposes and for use as a relay exciter in case of accident to either of the exciters direct-connected to the frequency changers. This auxiliary set consists of a 75 KW compound-wound, direct-current generator, direct-connected to an induction motor. The switchboard for controlling the step-down transformers and frequency changers is mounted on a gallery at one side of the motor generator room. It is of the usual marble panel type, the panels having mounted upon them the necessary instruments and the handles controlling the oil switches which are in the basement of the building. The oil switches for the control of the motor generator sets are of the mechanically operated type, while those for the control of the transformers are electrically operated. All of these switches are capable of acting as automatic circuit breakers. Those controlling the motor generators act as simple overload breakers, while those for the transformers have reverse time limit relays.

The plant was in operation delivering power in Montreal eight months after work was begun upon it. This means that new designs for the transformers, frequency changers and insulators were gotten out and the apparatus installed, tested, and put into operation in that time. As previously stated, it is now delivering at time of peak load something over 6000 horse-power. The voltage carried at the generating station with this peak load is 53,000 volts.

The first two of the generators installed, the step-up and step-down transformers, and most of the switchboard apparatus were furnished by the Westinghouse Electric & Manufacturing Company, of Pittsburgh. Some of the switchboard apparatus, however, was furnished by the General Incandescent Arc Light Company, of New York, notably a number of the electrically-operated oil switches and the interlocking selector switches. The General Electric Co., of Schenectady, N. Y., also furnished some of the oil switches. The third generator came from Messrs. Dick, Kerr & Co., Ltd., of Preston, England. The motor-generator frequency changing sets were furnished by the Bullock Electric Manufacturing Company, of Cincinnati, Ohio, U. S. A. The line insulators were made by the R. Thomas & Sons Company, of East Liverpool, Ohio.

ELECTRICITY AND LIGHT

By Charles Proteus Steinmetz



If the use of fire were the first step in the advance of the human race and the step which distinguished man from his animal predecessor, then the art of illumination is as old as the human race, for one of the first uses to which fire was put was undoubtedly illumination. Since these pre-historic ages the art of illumination has steadily advanced. From the stick of wood to the torch, the candle, the oil and kerosene lamp, the gas flame and the electric light, each illuminant in its turn has been replaced by one offering greater convenience, greater cleanliness, and greater steadiness and intensity. But still, from the fire of pre-historic ages to the electric arc lamp which now floods our streets with light, and the incandescent lamp which flashes up by the pressure of our finger, the methods of producing light have remained the same in principle. By some means heat is produced, and if the temperature is high enough a small percentage of the energy becomes visible as light; the rest is thrown away and wasted as heat.

The efficiency of light production is discouragingly low; in the candle, the kerosene lamp, the ordinary gas flame, probably less than 1 per cent. of the energy is realised as light. In the incandescent lamp an efficiency of perhaps 2 per cent. is reached, and hardly 5 per cent. in the carbon arc lamp, the most efficient source of light now in use.

While, therefore, the efficiency of electric lighting is higher than that of lighting by combustion and the use of the electric current for producing light so constitutes an advance, in other respects it is a step backward. The chemical energy of coal and oil used in the gas flame and the kerosene lamp is the lowest and cheapest form of energy, while electrical energy is a high-grade form more expensive to produce than the heat energy of combustion. What electric light, therefore, gains by its higher efficiency it loses by the inherently greater cost of electric energy. The advantage of modern electric lighting, by which it has succeeded and is succeeding to replace all the other illuminants, must, therefore, be found not so much in its greater cheapness as in its greater convenience, safety and steadiness, its ease of control and applicability to any position and purpose.

If we compare the efficiency realised in the production of light from electric energy, of perhaps 5 per cent. as a maximum, with the efficiency of producing mechanical energy in the electric motor, or electric energy from mechanical energy in the electric generator, where values of 90 per cent. to 97 per cent. are commonly realised, the present methods of electric lighting appear rather crude in their principle; it is really heat that we produce, and light appears almost as a mere by-product. While, therefore, no very essential advance in the efficiency of electric motors, generators, etc., is possible, electric

lighting is still in its very beginning. The amount of light produced from electric energy may well be increased tenfold, and the efficiency of light production would still be low compared with the efficiency of the electric motor.

In this direction, then, an enormous advance in the use of electricity can be hoped for in the future. If the efficiency of production of light from electric energy could be raised only to the efficiency of the poorest electric motor on the market, electric light would sweep all other illuminants out of existence by its cheapness. This is well realised by those in control of the electrical industry of to-day, and some years since many of the giant electrical manufacturing companies of this country and abroad have established extensive laboratories for the investigation and study of improved methods of electric lighting. In the last years avenues of research have been opened and are being energetically pursued in these laboratories, which promise to replace the present indirect and inefficient methods of light production by a more direct transformation of electric energy into light, with a far higher efficiency.

To understand in which direction this pioneer work is progressing, let us investigate the action of the incandescent lamp. The electric current flowing through the lamp filament supplies energy to the filament as heat and the temperature of the filament rises; the smallest particles or molecules of the filament are set in vibration, and, in their turn, send out vibrations or waves into the surrounding ether, just as a vibrating violin string or tuning-fork sends out waves into the surrounding air: only that in the ether, which is incomparably thinner than the air, the velocity with which the waves move is very much higher, about 200,000 miles per second, while the velocity of the sound waves in the air is only about 1000 feet per second. The greater the energy supplied, the higher the temperature of the lamp filament becomes, and the greater is the intensity of the vibration; that is, the more radiating energy issues therefrom.

If the molecules of the vibrating body were free to move independently of each other, as the molecules of a gas, they would vibrate with a pitch or frequency of their own, regardless of the amount of energy supplied to them, just as a violin string or tuning-fork will give a definite pitch. This, however, is not the case with the molecules of the carbon filament of our incandescent lamp. They are so close together as to interfere with each other, and so give, not a definite pitch, but a mixture of all existing frequencies or vibrations, just as a heap of sand, when vibrating, would not give a definite note. With but little energy supplied to the lamp filament, only slow vibrations appear,—slow from the point of view of ether waves. They may be as high as 300 millions of millions of waves per second. The human eye cannot perceive these waves, but the hand may feel them as heat radiation. With increasing temperature more rapid vibrations appear, and as soon as the temperature is high enough to send out vibrations of about 400 millions of millions of waves per second, or of a wave length of .0007 millimetre, these waves become visible as red light. With still further increase of the frequency of vibration, yellow light appears, then green, blue, and violet. As soon as the frequency of vibration exceeds 750 millions of millions of waves per second, the vibrations become again invisible to the eye, but will act on the photographic plate as actinic or ultra-violet light. In the range of very much faster vibrations the X-rays, etc., are to be found.

Of all the infinite variety of vibrations sent out by the heated body only the range from 400 to 750 millions of millions of waves per second, or something less than one octave, is visible to the eye as light; all the others are wasted as heat, etc. At a low temperature only slower vibrations or long waves appear, heat only being radiated. With increasing temperature visible rays appear in greater and greater quantity, but the increase of visible radiation is greater than the increase of total radiation, the higher the temperature, the greater a percentage of the total rays being visible

rays. The efficiency of light production is, therefore, higher.

In producing light by incandescence the highest possible temperature gives the best efficiency. Here, however, we soon strike an absolute barrier: any material will ultimately melt or evaporate. Carbon probably is the most refractory substance, and the boiling point of carbon is the highest temperature to which a solid can be raised. At this temperature the visible rays probably still amount to less than 10 per cent. of the total rays, making the efficiency of light production still less than 10 per cent. even if the enormous loss of heat by conduction and convection could be avoided. In a carbon arc lamp the crater of the positive carbon is at the boiling point and gives the most efficient incandescent light, making the carbon arc lamp the most efficient illuminant. In the incandescent lamp a much lower temperature is necessary to avoid too rapid self-destruction, and so a lower efficiency results. In producing light by combustion no temperatures like these can be realised, since far below the temperature of the arc chemical affinity has disappeared and combustion ceased. This accounts for the still much lower efficiency of light production by combustion.

Only solids and liquids follow the temperature law of radiation, by which the ratio of visible to total radiation is a function of the temperature, increasing with the increase of temperature. In any substance in which the molecules can move independently of each other, as in gases, especially at reduced pressure, the vibrations of the molecules, like those of a tuning-fork, are of a definite period or wave length, or usually a number of wave lengths. Sodium vapour, when luminous, gives out radiations only of the wave length .00059 millimetre; mercury vapour gives radiations of a few definite wave lengths only. Here, then, the temperature law does not apply, but the ratio of the visible to the total radiation depends on the chemical and physical characteristics of the gas and may be very high. A large percentage of the wave lengths given by the luminous gas molecules may be within the octave of visible light, as with mercury or titanium. With other substances, as with carbon and silicon vapours, most of the waves may be outside of the visible range, and such vapour molecules would give a non-luminous radiation, or practically such.

Unfortunately, when supplying heat to a gas we do not get vibration, as with a solid or liquid body, but rectilinear motion of the molecules, which appears as mechanical pressure and not as radiating energy. Heating a gas expands it, but does not make it luminous to any extent. Vibration of the gas molecules to produce light can, however, be brought about by other means, such as chemical reactions and electrical excitation.

Gases and vapours are made luminous by electrical excitation, either by the electrostatic spark, as in the Geissler tube, or by the electric arc. A spark is made by the passage of an electric current over a gap between conducting terminals through the gas or vapour filling the space. To produce a spark the voltage or electric pressure has to be raised until it breaks down the gap between the terminals. This usually requires a very high voltage, but only a small current. The electric arc is made by the passage of a current across a gap through a conducting vapour bridge formed by the material of the terminals, at relatively low voltage but high current. The arc does not start itself, the vapour bridge having first to be formed, either by jumping a spark across the gap or by bringing the two terminals into contact with each other and then separating them. A bridge of vapour, at the temperature of the boiling point of the material of the terminals, is thereby left behind, which is constantly replenished by evaporation from the terminals. Such an arc may be formed either at atmospheric pressure or in a vacuum. The carbon arc is the hottest of electric arcs, while mercury has such a low boiling point that the mercury arc can be, and is, enclosed by a gas tube.

Experiments are also being made on

the production of luminosity in gases by the electrostatic spark in a partial vacuum, as in the Geissler tube; but the great difficulty seems to be in the high voltage required and the low intrinsic brilliancy of the Geissler tube glow, which requires the use of enormous surfaces to produce sufficient illumination.

Metal salts introduced in a non-luminous gas flame make it luminous by giving their characteristic metal spectra, as: sodium salts, yellow; lithium, red. Here the luminosity of the metal vapours is probably due to chemical reaction. A much greater brilliancy than that obtained by the use of a gas flame can be secured by introducing such metal salts into a carbon arc, the latter being very much hotter than the former. The best way is to incorporate these metal compounds into the positive carbon terminal, that being the hotter, and, therefore, giving more rapid evaporation. Arc lamp carbons impregnated with metal salts, so-called flame carbons or effect carbons, are now on the market. They give, in addition to the light of the incandescent carbon crater, an additional light from the arc flame, and so an efficiency much higher than the ordinary carbon arc. Their main drawback, however, is that they must be operated as open arcs; they cannot be protected from rapid combustion by an air-tight enclosing globe, since the metal salts produce a smoke or dust which has to be carried off. Such flame carbon arcs, while far more efficient than the ordinary enclosed arc of to-day, are what is called "short-burning": the carbons have to be replaced or the lamp trimmed every day, while the enclosed lamp needs attention once a week or less frequently. To-day the short-burning or open carbon arc has almost entirely been replaced by the long-burning or enclosed arc. Whether the high efficiency of the flame carbon arc will be sufficient to compensate for the short life of the carbons and so reintroduce the open arc, remains to be seen.

The number of substances which can be used to give luminosity to carbon arcs is rather limited, and thus far the only materials which give a great increase of light are calcium compounds, mainly calcium fluoride (fluor-spar). They are almost always used in flame carbons, producing a reddish-yellow light which shows colour values very different from daylight. In these flame carbon arcs the current is carried by carbon vapour, as in the ordinary arc, and the light is given by the metal salts, probably indirectly, by the heat of the carbon vapour causing chemical reactions.

A direct method of producing luminosity in vapours is found by using them instead of carbon as carriers of the current in the arc, replacing the carbon altogether by some other conducting substance which gives a luminous flame. Typical representatives of such luminous arcs, which probably approach nearer than anything before to the direct conversion of electric energy into light, are the mercury arc and the magnetite arc, both of which are now appearing before the public. They seem to be the first step in a radical advance of the art of electric illumination.

In the mercury arc the current is carried by mercury vapours. At least one of the terminals must consist of mercury, and to avoid the escape of mercury vapours into the air the arc is enclosed in a glass tube from which the air is thoroughly exhausted, so that the arc completely fills the tube. In consequence, the mercury arc is absolutely steady and no consumption of material takes place, and its life, which may reach thousands of hours, is limited only by accidental destruction of the glass tube. The light of the mercury arc is of a greenish-white hue, deficient in red rays, so that colours are not represented in their correct daylight values. This feature for certain purposes limits the use of the mercury arc, but the absence of red rays eliminates the harmful effect of ordinary artificial illumination which is almost exclusively due to the red rays preponderating in the light of the ordinary illuminants.

Where work is to be done for considerable periods with artificial illumination, and for street or park lighting the

mercury arc appears especially suited. Its efficiency is extremely high. The mercury arc gives from three to four times as much light as a carbon arc consuming the same power, and about six times as much as the incandescent lamp.

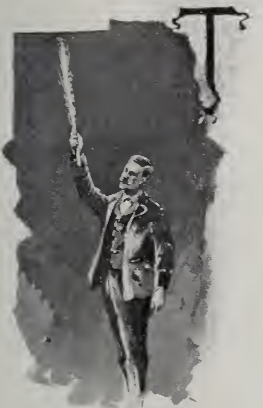
The magnetite arc lamp is the result of an extended investigation into the methods of improving the efficiency and character of arc lighting. As essential requirements of a satisfactory illumination may be considered high efficiency, steadiness, long life, convenience of operation and white colour of light. A study of the spectra of metals showed that the metals of the iron group, iron titanium, etc., give a luminous arc in which the different colours are represented in the same proportion as in the light of the sun, and that these metals, therefore, are best suited as carriers of the arc flame.

The arc terminals or electrodes obviously must be conductors, and since the arc must be operated in open air, a non-combustible material becomes necessary. For this purpose are used the metallic oxides, which, being already combined with oxygen, cannot burn. Most metal oxides, however, are non-conductors of electricity and so not suitable. In magnetite or the black oxide of iron, one of the most common iron ores, a material was found which is absolutely stable at all temperatures, is a conductor, and gives a brilliant white arc, especially when combined with the oxide of titanium, etc.; hence it appears especially suitable to replace the carbon used heretofore in the arc lamps. The rate of consumption of such electrodes is extremely low, since only the very small amount of material is consumed which is required to carry the current. While an ordinary carbon pencil, when used in the open arc lamp, will be consumed at the rate of one to two inches per hour, with magnetite pencils of the same size rates of consumption of 50 to 100 hours per inch have been reached. The efficiency of the magnetite arc is fully as high as that of the mercury arc, and very much higher than that of any other illuminant ever used. This follows from the more direct transformation of the electric energy into light.

The introduction of the magnetite arc as a source of illumination marks the beginning of a new era in the direct conversion of electricity into light as opposed to the production of light with heat as an intermediary, exemplified in the incandescent lamp. The matter is still in its infancy, however, and the future opens up a broad field for investigation in this line.

ELECTRIC WELDING DEVELOPMENT

By Elihu Thomson



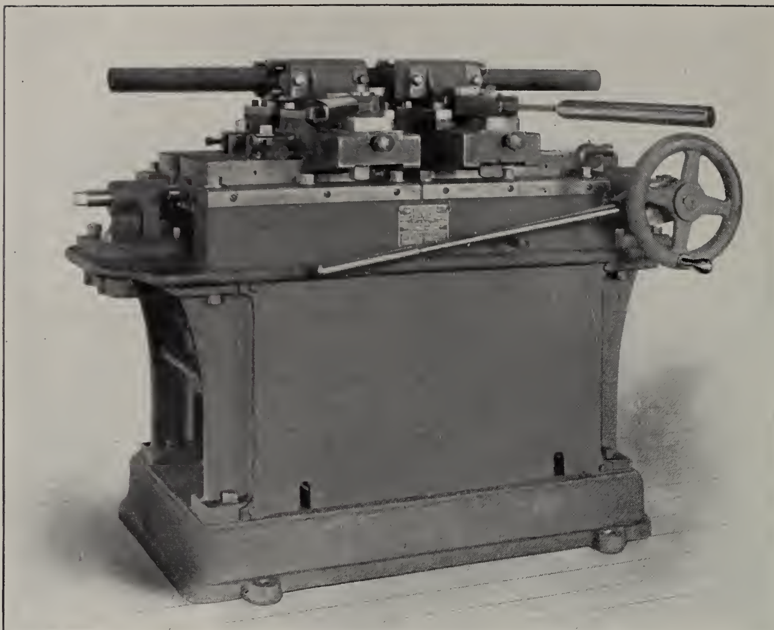
THE art of welding iron is probably as old as the earliest production of that metal by man; in fact, the reduction of iron in the primitive forges demanded the union by welding of the reduced particles, for no true fusion could have resulted, the percentage of carbon present being too low. Until the closing years of the last century iron was the only weldable metal, if we except gold and platinum,—too expensive for common application.

The fact that nearly pure iron, so difficult to melt, becomes quite plastic at high temperatures, while the oxide or black scale melts long before the metal itself becomes fluid, thus providing a liquid flux which is squeezed out during the process of union, accounts for the unique position which iron held until recent years. When, however, the heating effects of electric current energy, so perfectly under control, were applied to weld metals, a metal or alloy which would not weld became the exception, instead of the rule, as before. Much of the former work of the smithy fire is now accomplished by the electric welding transformer, and although many metals are easily manipulated by the electric process, iron, of course, still occupies, as ever, the principal place.

The electric weld is becoming a more and more important factor in many industries. During recent years the extension of its application has been steady, and each year has witnessed its entrance into new fields. Sometimes, indeed, new manufactures, or new ways of obtaining results have been based upon its use. The electric welds under consideration are the results of that operation of uniting two pieces of metal by what is known as the Thomson process, first brought out by the writer and rendered available in commercial practice a considerable number of years ago. The rapidity, flexibility, cleanliness, neatness, accuracy, and economy of the electric process has won for it such an important standing in the arts that many future extensions in its application are assured.

The uniformity of the work, the control of the operation, the extreme localisation of the heat to the particular parts to be united, and the fact that the process is not limited to iron and steel, but can deal equally well with other metals, such as copper, brass, bronzes, and even lead, are characteristics of the electric welding operation.

In its simplest form, an electric welder consists of a special transformer, the primary circuit of which receives current from an electric station or dynamo generator, at a voltage usually from one hundred to five hundred times that required to make a weld. The copper secondary circuit of the transformer is generally only a single turn of very large section, so that it may develop an extremely heavy current at from two to four volts,—an electric pressure so low that it cannot give the least effect of shock, and one for which there is no difficulty in securing perfect insulation. The work pieces are held in clamps or vises, attached to or carried upon the terminals of the single-turn secondary circuit. The control of the clamping devices and the current switch is either manual, or, in some cases, entirely automatic. Without attempting to enumerate the many applications of electric



AN ELECTRIC WELDING MACHINE FOR IRON AND STEEL PIPE. COILS AND BENDS OF PIPE CAN BE WELDED IN THIS MACHINE

welding in the arts, we may refer to a few examples.

In the waggon and carriage industry the process is applied in the production of tires of all sections, axles, hub, spoke and sand bands, fifth wheels, shifting rails, steps, shaft iron, etc., while it has found a large use in the welding into continuous strips or bands of the wires inclosed in rubber tires for holding them in place. The larger part of the dash-frames used in carriages in the United States are now probably made by electric welding, while iron and steel agricultural wheels are built up, or have their parts united, by electric welds.

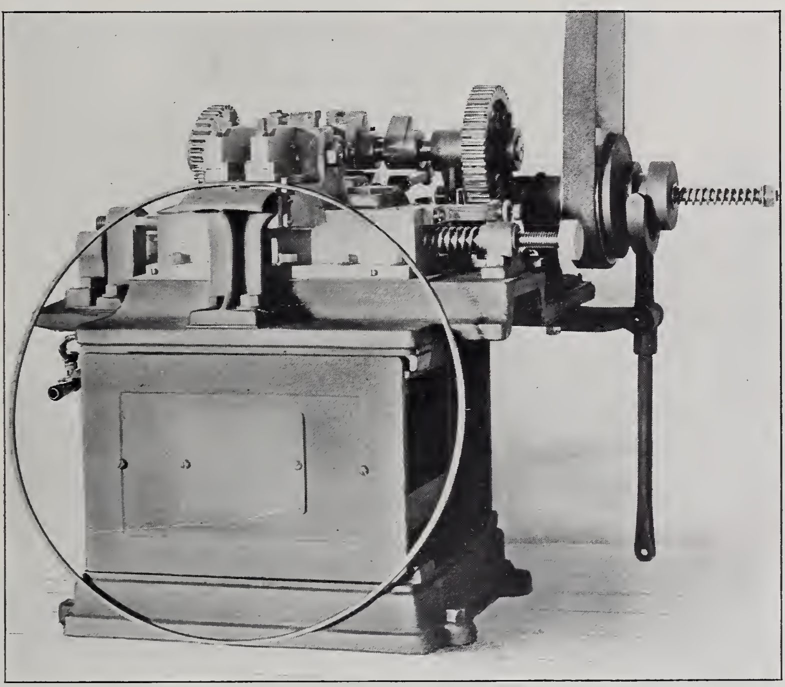
To enumerate the many applications to the bicycle industry would be almost to catalogue most of the metal parts of this useful machine. It must be borne in mind, too, that a welding machine, slightly modified, is equally applicable for locally heating parts in electric brazing or hard soldering, for upsetting, and for bending or shaping. Bicycle crank hangers, pedals, seat-posts, fork and fork ends, frames and brake parts thus become products in which the welding transformer has its part. It has found a useful field also in tool manufacture, such as drills, reamers, taps, band and circular saws, drawing knives, carpenter's squares, printer's chases, etc., etc., and electric welding has a closely related use in the production of machine parts. Cam shafts and crankshafts are made from drop forgings welded together, teeth are inserted into gear wheels, and teeth are welded to saw bodies, including stone saws. Such things as inking rolls in printing machines and fallers for looms are additional examples.

In the wire industry the part played by electric welding is already quite important, and becomes steadily more so. Besides the mere simple joining of wires of iron, steel or copper into long lengths, the welding of wire or strip into hoops for barrels, tubs, pails, etc., is supplanting the older forms. Numerous machines are in operation turning out electrically-welded wire fence, much as a loom turns out cloth.

In pipe bending and coiling, as in uniting ordinary lengths of pipe into

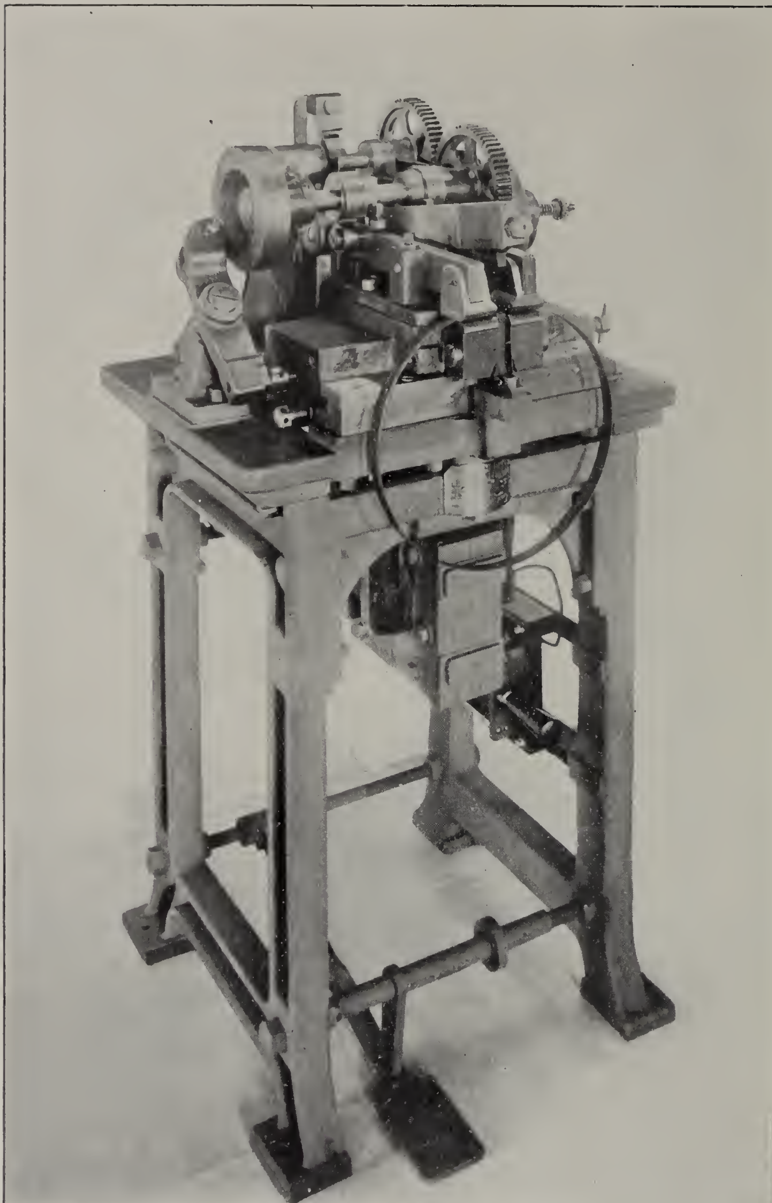
very long lengths without screw joints, the electric weld has a special adaptability. Hundreds of miles of street railway rails have been welded into continuous lengths and now exist in many cities. Where rails are bonded only, the electric welder assists in the production of brazed or welded bonds. It is a wide range between buckles, typewriter bars and umbrella rods to the local annealing of armour plates on warships, but the electric welder covers that range. It is no wider, however, than that from fine wires of a diameter of one-fiftieth of an inch up to heavy steel wire for the armour of submarine cables, and again up to street railway rail joints.

In recent years, elaborate machinery, for the actual production on a large scale of steel tubing from flat stock or skelp by the progressive welding of a longitudinal seam, has been put into operation. The long strip, or skelp, is rolled up so that its edges meet. In this condition it enters between the welding rolls, which pass the heating current locally across the edges to weld them, and the operation is progressive from one end of the pipe to the other as it is fed into the machine. The result is a pipe of which the walls are of even thickness and the diameter uniform. This pipe can be afterward drawn, if needed, to the exact size desired. Very thin pipe can be made of steel, the longitudinal seam or weld in which is a delicate bead along the length,—a beautiful product, for the extreme localisation of the heat has allowed preservation of surface and finish of the metal outside the joint. Taper tubes, such as are used for bicycle front forks and the like, are easily made.



AN ELECTRIC TIRE WELDING MACHINE, MADE BY THE THOMSON ELECTRIC WELDING CO., LYNN., MASS.

A similar machine for large work has lately been constructed, and by its use large diameter tubes or shells, up to 16 inches in diameter, are produced from sheet steel or iron. The illustration on page 232 shows such a machine ready for operation. The welding transformer



ANOTHER FORM OF HOOP OR TIRE WELDING MACHINE

is at the top of the machine, and the secondary circuit has for its terminals two copper rolls inclined to each other on two nearly horizontal shafts adjustable in position over the work. Below are the guide rolls, one on each side on vertical shafts, and between these the shell to be welded passes with its meeting edges uppermost and in contact with the copper contact rolls. As the metal shell passes along under these rolls the joint is progressively heated by the welding current crossing it, and the weld is finished by the side pressure of the

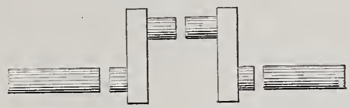
guiding rolls. The process, as well as the resulting welded product, is unique.

For a considerable time past welding machines have been applied to the production of bands or tires from stock of varying width, thickness and sectional form. More recently the practice of welding plain bands or cylindrical rings, and afterwards rolling them with the form of section desired, has been largely adopted; such as, for example, in the production of automobile wheel rims, bands for roving cans, stove rings, etc.

Very different from this is the formation of crankshafts, now demanded in great numbers for engines of automobiles. These are made from drop forgings and round shaft stock by uniting the pieces, as in the annexed sketch, and afterwards lightly machining and finishing the approximately correct shaft, as produced by welding.

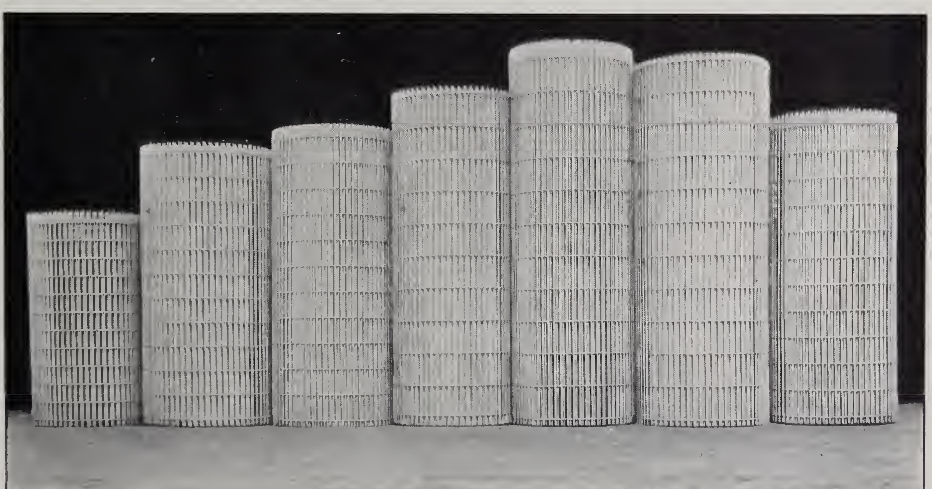
Besides the banding of wire or strip of such comparatively frail containing vessels as barrels or pails, the electric weld finds application in the forming and capping of metal vessels for withstanding high pressures, such as soda-water cylinders, carbonic acid reservoirs, and steel bottles for nitrous oxide gas.

One of the most interesting of the more recent applications is that of welding hollow steel handles on cutlery, such as table knives and forks. The operation is remarkable for the celerity and neatness of the work, the articles being finished by silver-plating and polishing, as usual. The hollow handle is drawn from thin steel, and united to the knife blade or to the fork, as the case may be, in a special welding machine, there being no brazing or other operation of joint-forming required. There is, indeed, no limit to the delicacy of the

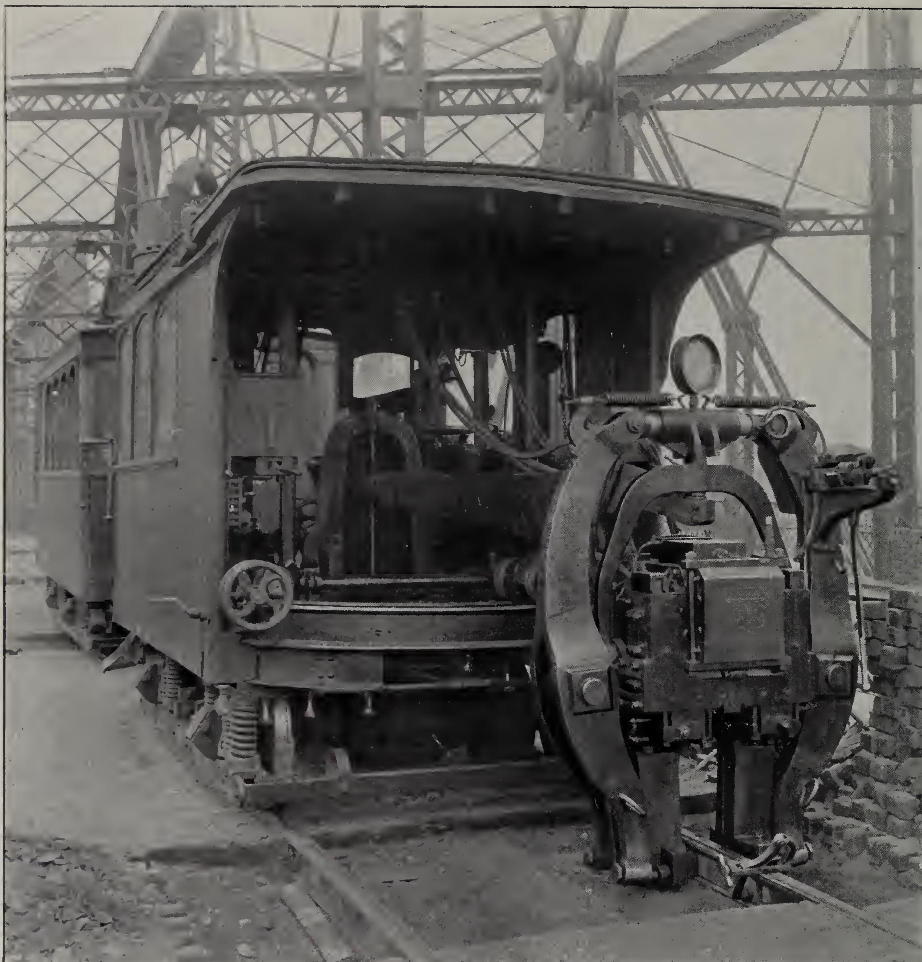


work which may be undertaken, provided only the welding apparatus is equally refined.

In the simpler types of electric welders, especially where the machine is designed to do a variety of work, perhaps of different forms or sizes of pieces, or both, the adjustments are usually manual; that is to say, the operations of clamping the pieces and applying the electric current and mechanical pressure are each controlled by the operator. In other cases, such as in the welding of copper or aluminium wire, the machine is, at least in part, automatic. The pressure is automatically applied and the welding current is cut off automatically upon the completion of the joint;



ROLLS OF ELECTRICALLY WELDED WIRE FENCE OF VARYING WIDTH AND MESH



ELECTRIC RAIL WELDING ON STREET RAILWAYS, AS PRACTICED BY THE LORAIN STEEL COMPANY, JOHNSTOWN, PA., AND LONDON

the placing of the pieces in the clamps and the switching on of the current is, in this case, manually performed.

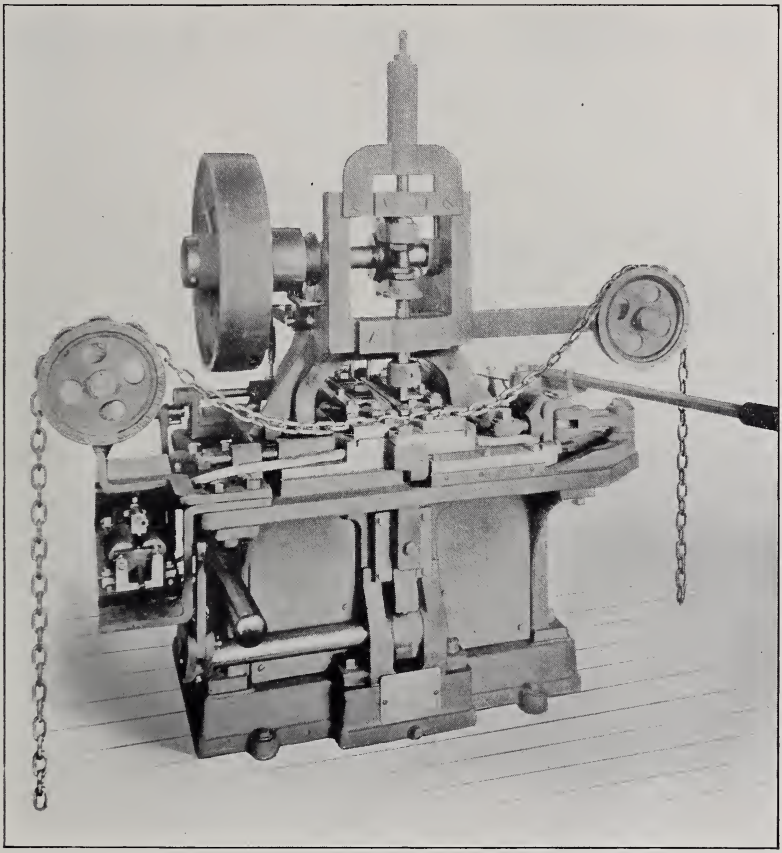
In other, more completely automatic, types, particularly adapted for rapid repetition of the same operation on identical pieces, the machine runs continuously, and its sequence of actions is definitely determined by the construction. In such cases a source of power, as by a belt, drives the machine, the movement so imparted having the effect of clamping the pieces as they are fed to the machine, putting on the current, applying the pressure, cutting off the current and releasing the pieces.

The mechanism which has been developed for these purposes displays, in many instances, much ingenuity. In these machines the duty of the attendant is limited to the mere placing of the pieces between the clamping jaws, just before they are clamped, and the work is characterised by rapidity and by uniformity of the results.

More completely automatic still are machines for the production of wire fencing and for the consecutive welding of the links of chains. In these the operation, once started, goes on uninterruptedly so long as the work holds out, or until the stock undergoing operation

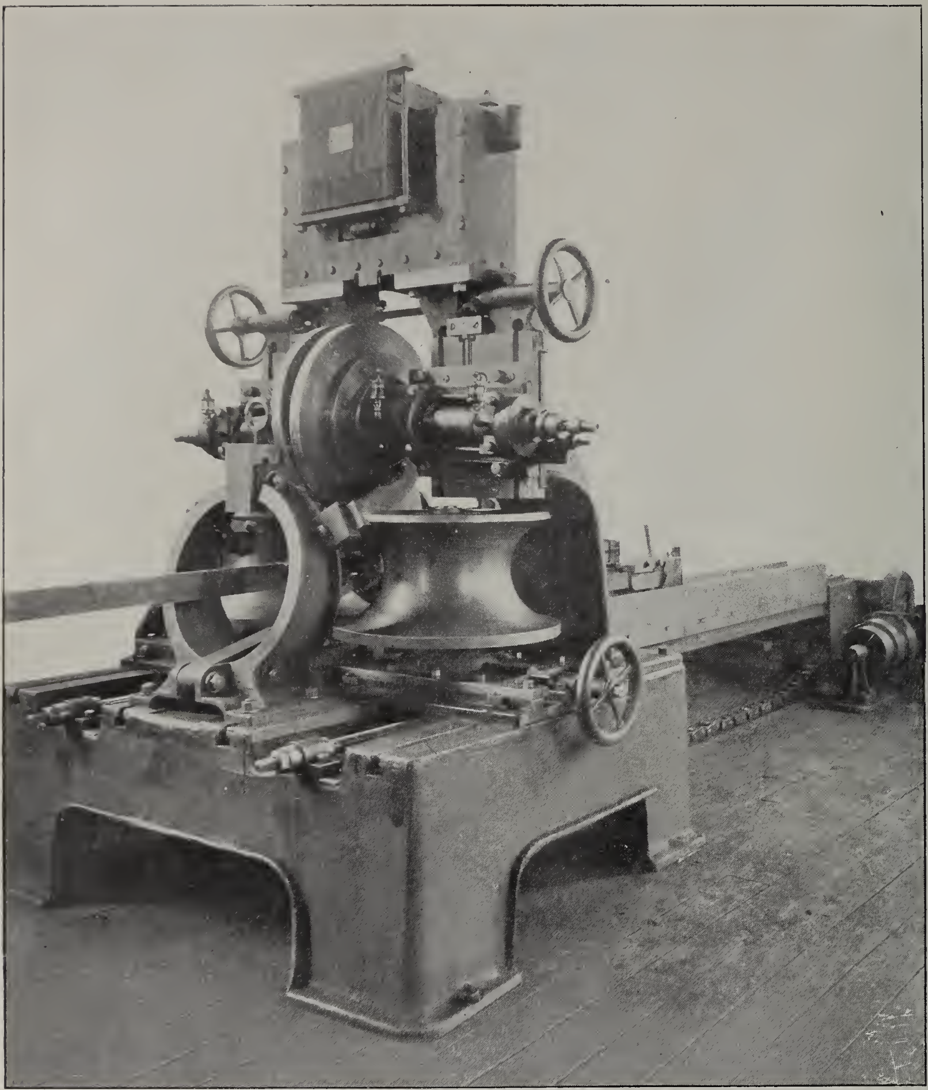
is exhausted. In the fence machines, of which fifteen are now in existence, galvanised iron wires are fed from reels parallel to one another, at distances apart depending on the mesh desired. These may correspond to the warp in weaving. Transversely to these, and at intervals corresponding to the mesh selected, are fed wires, cut from a reel, which transverse wires are the verticals in the finished fence itself and correspond to the weft in weaving. A series of small welders are automatically brought into operation to weld each transverse wire to the longitudinals where the two cross This done, the web so formed moves forward, the operation repeats itself, and so on continuously. The welding is, in this case, practically instantaneous, and all of the movements of the machine are entirely automatic.

In this way it is possible for a single machine to turn out many thousands of feet of fencing per day with a width of mesh from 2 or 3 inches up. Less wire is used than where the joints are made by twists or loops, and the stability or fixedness of position of such joints as are made is much more assured. The illustration on page 229 will give some idea of the neatness of this product of the electric welding loom.



AN ELECTRIC CHAIN WELDING MACHINE

While in most cases of electric welding the joint forms what is known as a butt weld, with a burr or extension of metal at the joint, which, according to conditions, is either allowed to remain



A WELDING MACHINE FOR LARGE TUBES OR SHELLS UP TO 16 INCHES IN DIAMETER, USED BY THE STANDARD WELDING CO., OF CLEVELAND, OHIO

or is forged down or dressed off, there is no difficulty in making lap welds electrically, and some of the recent work of the electric welder is of that character. While, too, the usual welding concerns pieces of the same metal, as iron to iron, steel to steel, or copper to copper, combination welds of different metals are made with facility in many cases, as when brass and iron are united.

In the working of high-carbon steels the usual precautions to prevent burning or injury to the metal are, of course, required; but, on account of the delicacy of heat control, they are more easily adopted.

Quite recently automatic chain welders have been put into use, and electrically-welded chain work will probably soon attain an importance not second to the other principal applications which have been briefly described.

SOME BRITISH CENTRAL ELECTRIC POWER STATIONS

By H. F. Parshall, M. Inst. C. E.

THE design of electric power stations is subject to so many special considerations that it is hardly possible to generalise. Thus, in the case of the Dublin United Tramways power station, it was commercially correct to locate the station in the centre of a continuous-current system of distribution and yet have proper coaling and condensing facilities. A station so situated has important advantages in that transformation and substations are avoided, and the problem of dealing with return currents, so as to avoid electrolysis, is greatly simplified. This state of affairs exists electrically, but infrequently mechanically, in installations of the ordinary extent and working from 200 to 300 cars.

In the case of such large installations as the Glasgow Corporation Tramways it would not be possible for a single central power station, no matter where located, to satisfactorily work the traction service without the use of substations. The situation of the Central London Railway makes it impossible to locate the power station in the centre of the system; consequently, even with the short length of line (only six miles), it is necessary to employ three substations and the multiphase type of generating plant. In the case of the Bristol power station, in order to secure the electric advantages incident to a central location, as also the advantages of direct coal supply and water for condensing, a station almost unique in Great Britain was designed, since with the site available it was possible to put down the necessary amount of plant only by arranging the power station so that the boiler room is above the engine room, and the coal storage above the boiler room.

The design of the Yorkshire power station is illustrative of the saving in building and space incident to the use of steam turbines. This is the most recent development, and, as compared with stations using reciprocating engines, the design is extremely compact. Turbine stations possess engineering advantages over stations worked by reciprocating engines, but the most important advantage is in capital cost.

In the following pages brief descriptions are given of some of the more important power stations designed by the writer during the last few years. These stations all are representative of good modern practice in Great Britain.

THE DUBLIN UNITED TRAMWAYS POWER STATION

The Dublin United Tramways power station, shown in Fig. 1, was designed in 1896, and is of interest on account of its being equipped with both direct-current and three-phase machinery, the direct-current plant being for the operation of the tramways in Dublin itself, and the three-phase plant for supplying the Clontarf and the Dublin Southern Tramways, both of which were operated electrically before the system in the city itself was changed over. At that time each had its own generating station, and the Dublin Southern was provided with two substations. These generating stations are now converted into substations, and the whole system is supplied with power from the station at Ringsend.

The main generating units are six in number, each of 500 KW, five being

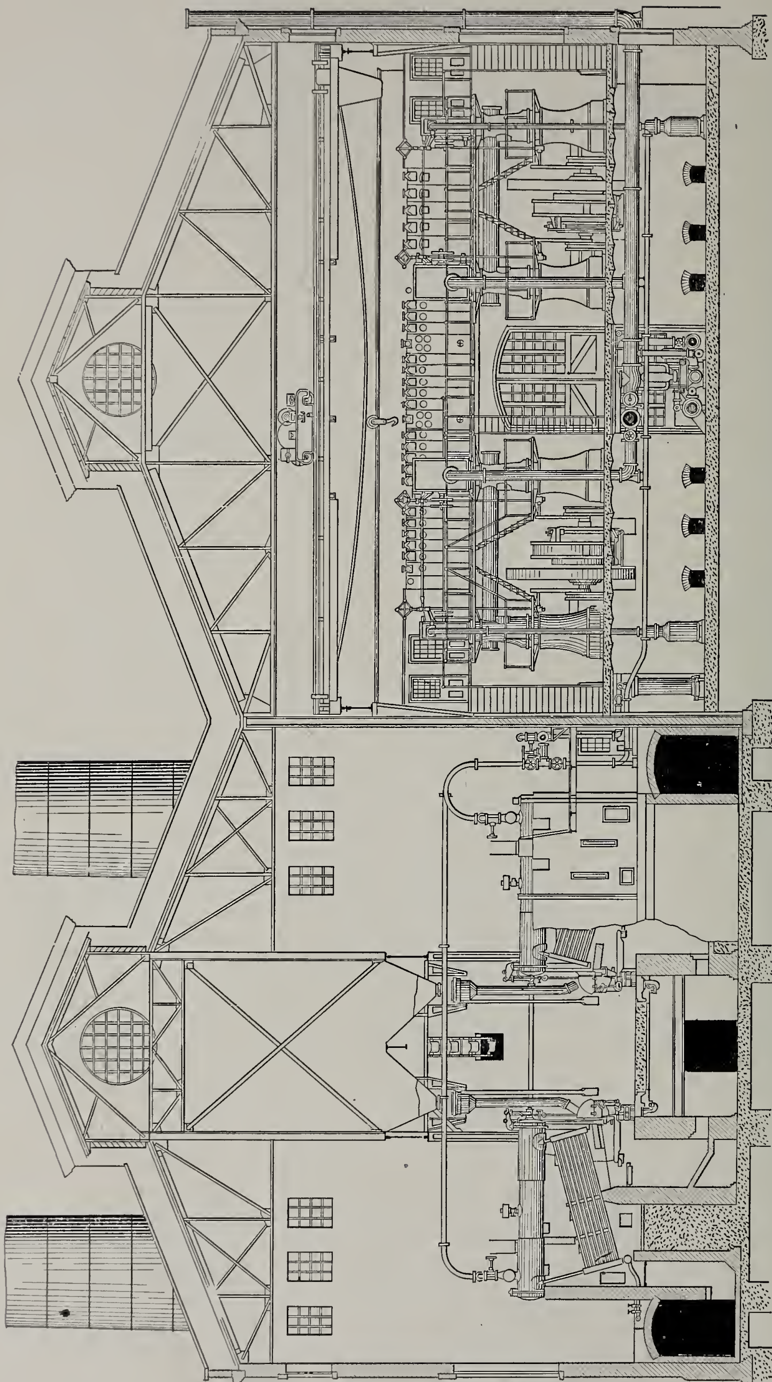


FIG. 1.—A CROSS SECTION OF THE DUBLIN UNITED TRAMWAYS POWER STATION

direct-current units at 500 to 550 volts, and the sixth, a three-phase machine at 3000 volts and 25 cycles. Each is mounted between the cranks of a vertical, cross-compound Corliss engine, running at 90 revolutions per minute, and giving 630 I. H. P. as a most economical load and 800 as a maximum continuous load with steam at 150 pounds per square inch and 27 inches vacuum. The cylinders are 20 and 40 inches in diameter, the stroke being 42 inches.

As a stand-by to the alternator there are two reversible rotary converters, each of 250 KW. These can be supplied with direct current from the traction switchboard, and furnish alternating current, which is transformed up to 3000 volts for the three-phase supply.

For each pair of units there is a surface condenser of 2700 square feet cooling surface with steam-driven combined air and circulating pumps, the whole being mounted on one bed-plate. The circulating water is obtained from the dock alongside of which the station is built.

Steam is supplied by twelve water-tube boilers, each having 2530 square feet of heating surface. The boiler pressure is 160 lbs. per square inch. The boilers are fitted with Vicars stokers. A steel flue is provided for each line of boilers, and an economiser with a byepass is fitted in each flue.

The stokers are supplied with coal from overhead bunkers, into which coal is lifted from an outside coal store by means of a motor-driven bucket conveyor. The outside coal store has a capacity of 2000 tons, and the coal is delivered to it by means of a hoisting tower and automatic railway. The hoisting tower has a grab by which coal is raised from barges alongside the generating station wharf and which deposits its load in a small waggon. The latter, when loaded, travels down an incline, dumps the coal into the store, and is returned to the hoisting tower by means of a counterweight. The coal is, therefore, never touched by hand. This is the first instance in Great Britain of such an arrangement. The building is a steel structure with brick panelling walls, and the flues and stacks are also of steel.

THE BRISTOL STATION

In the case of the Bristol station, shown in Fig. 2, what is known as the "double deck" design was adopted, owing to the exigencies of the site, which was, in other respects, a very desirable one. It will be seen from the illustrations that the building rests entirely on piles on the river bank, and is arranged in four stages. The lowest, or basement, contains part of the condensing machinery and piping; the next, or first floor, has the remainder of the condensing plant, the main engines and switchboards; the second floor contains the boiler and feed pumps, and the top floor the economisers, flues, water tanks and coal bunkers.

There are four main generator units, each consisting of a 500 KW, 500 to 550 volts generator, with the armature mounted on the shaft between the cranks of a vertical cross-compound Corliss engine developing 800 I. H. P. with steam at 150 lbs. per square inch and 25 inches vacuum. There are also two lighting units, consisting of 50 KW, 6-pole, 500-volt generators direct-coupled to engines running at 400 revolutions per minute, developing 75 H. P., non-condensing. Each pair of main units is provided with a surface condenser with 3200 square feet of cooling surface, with steam-driven air pumps and motor-driven centrifugal circulating pumps. The circulating water is drawn from the river.

The boiler room contains eight water-tube boilers, each having a heating surface of 3140 square feet. These are fitted with Vicars stokers which are motor-driven. The bunkers are supplied with coal by means of a continuous bucket conveyer with a capacity of forty tons per hour.

The coal is raised from barges by a grab, as in the case of the Dublin station; but as there is no outside store, the grab dumps the coal into a hopper, whence it passes direct through an automatic filler into the conveyor. The flue is of brick, with the usual byepass ar-

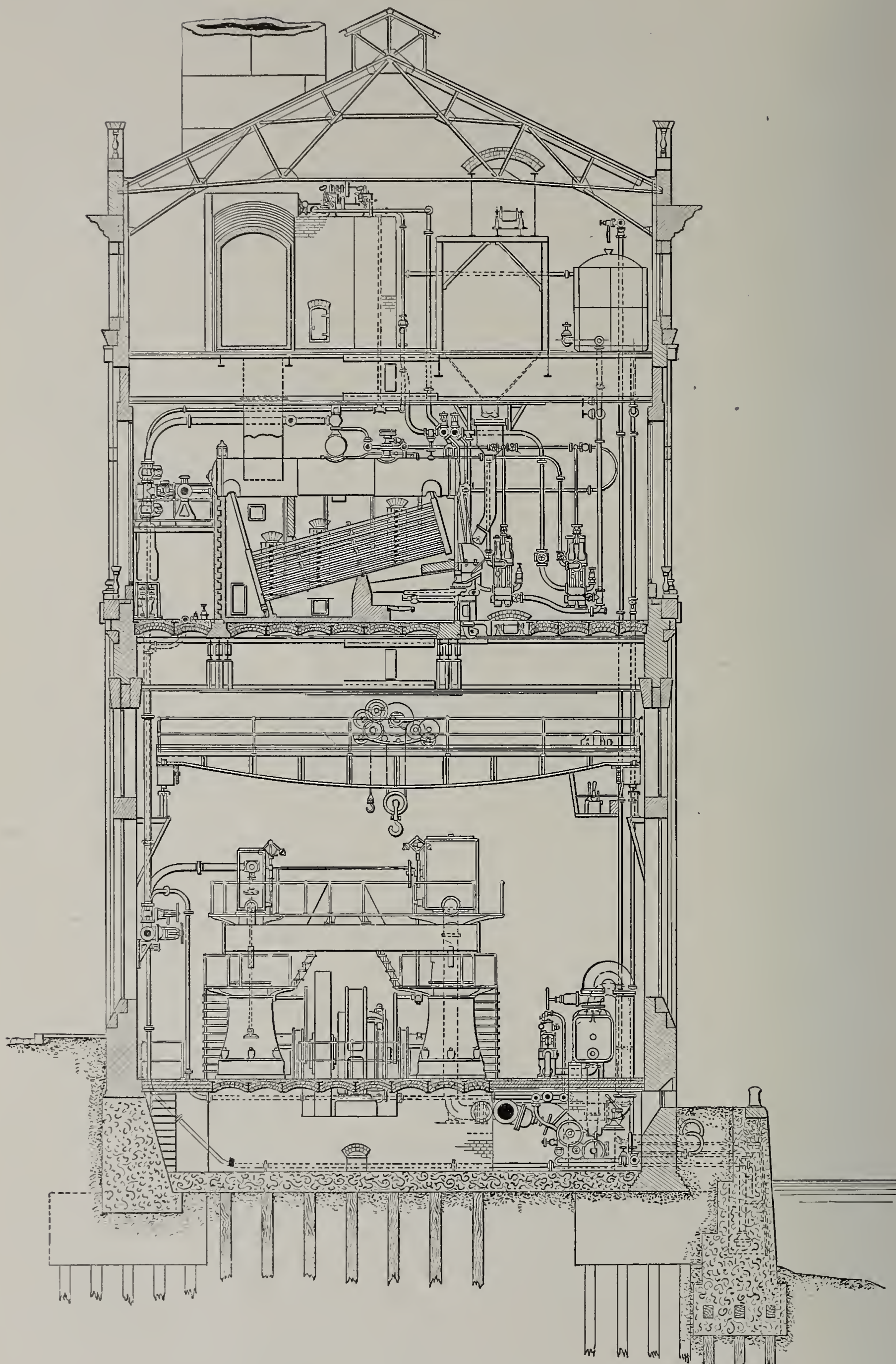


FIG. 2.—THE BRISTOL POWER STATION

rangements for the economiser. The station building is a steel structure, with steel and concrete floors and brick panelling walls. The stack is of steel, and of similar construction to that at Dublin.

THE CENTRAL LONDON RAILWAY POWER STATION

The next station of importance is that for the Central London Railway. This is of particular interest electrically, since this railway was the first heavy traction installation worked by means of rotary converter substations. The general arrangement of the station is well shown in Fig. 3.

There are six main units, each consisting of a horizontal cross-compound engine with Reynolds-Corliss valve gear, driving a three-phase alternator of the revolving field type with the field magnet mounted on the shaft between the cranks. The generators are 850 KW machines, with a voltage of 5000 and a frequency of 25 cycles, running at 94 revolutions per minute. The engines are designed for maximum economy at 1250 I. H. P., and a maximum continuous capacity of 1900 I. H. P., with steam at 150 lbs. per square inch and 26 inches vacuum. The steam consumption under these conditions at the most economical load is 13.3 lbs. per I. H. P. per hour.

The number and size of the units was fixed by the estimated power for twenty-five trains, together with lifts and lighting. The average load for these requirements was estimated to be about 3400 kilowatts. Allowing for the large and sudden variations in load, it was thought desirable to provide for 4000 KW during the maximum service and allow one unit space. A fairly large number of units was considered advisable to obtain economical working over a wide range of loads. With the locomotives formerly in use, the actual maximum number of trains operated never exceeded twenty-four, and owing to the way they were handled, a low acceleration being employed and but little coursing done, the fluctuations of current were less than were expected, so that four units were found capable of dealing with the maximum load. With the new motor-trains the average load per train is much reduced, so that four units can easily supply the power for the twenty-eight trains now run at the hours of maximum service, together with the lifts and lighting.

Each engine has a separate jet condenser with steam-driven pumps, located in the basement, each condenser being adjacent to the engine to which it is connected. There being no large supply of water available, the circulating water is cooled by means of three cooling towers into which it is lifted by three direct-drive steam pumps, one of which is a spare.

Two of the cooling towers are of the natural draught type, and the third has fans to be used in case of emergency demands.

The exciting current is supplied by four direct-current units, consisting of 50 KW, 125-volt generators direct-coupled to vertical, tandem, compound engines running at 400 revolutions per minute, and capable of developing 80 I. H. P. as a maximum, and there are two generators of the same output at 500 volts for lighting and power supply when the main plant is shut down. There are three direct-driven steam feed pumps, the water for the boiler feed being obtained from a deep-level well, from which it is raised by compressed air. All the auxiliary steam plant exhausts into an auxiliary surface condenser with steam-driven, direct acting air and circulating pumps.

Steam is supplied from sixteen water-tube boilers, each with 3580 square feet of heating surface, and four Lancashire boilers. The water-tube boilers, however, are quite sufficient for all purposes, ten of them being ample to supply steam for the maximum load.

The coal is stored in overhead bunkers in the boiler room, into which it is raised by means of a motor-driven bucket conveyor with a capacity of 40 tons per hour.

There is a separate flue and stack for each line of boilers, each having an economiser, with the usual bypass arrangements.

THE GLASGOW CORPORATION TRAMWAYS STATION

This station, shown in Fig. 4, was designed to deal with the most extensive system of street cars in Great Britain, the buildings being constructed to contain plant to operate 900 cars, and plant for 600 of these being installed. This plant consists of four main and two auxiliary units. The system, like that of the Central London Railway, is operated by means of three-phase transmission, with rotary converter substations.

Each of the four main units consists of a 40 pole, 2500 KW, 6500-volt, three-phase generator of the revolving field type, the field being mounted direct on the shaft of a three cylinder, vertical, compound engine running at 75 revolutions per minute. The engines develop 4000 I. H. P. at their most economical load, and 5000 I. H. P. as a continuous maximum, with steam at 150 lbs. per square inch and 25 inches vacuum. In two of the engines the high-pressure cylinders are 42 inches and the low-pressure 60 inches in diameter; in the other two engines they are 42 and 62 inches, respectively, the stroke in every case being 60 inches.

The valve gear of all four engines is of the Corliss type. The steam consumption, as determined by the official tests, is 12.2 lbs. per I. H. P. per hour under the conditions as to load, pressure, and vacuum given above. The exciting current is supplied by six generators, each of 50 KW at 100 volts, direct-coupled to vertical, cross-compound engines running at 300 revolutions, and developing 85 H. P. at their most economical and 100 I. H. P. at their maximum continuous load.

The two auxiliary units are for the supply of direct current at night when the substations and main plant are shut down. Each consists of a direct-current, 10-pole generator, of 600 KW at 500 volts, driven by vertical, cross-compound engines developing 800 I. H. P. at the most economical and 1000 I. H. P. at their maximum continuous load. The armature is mounted between the cranks in each case. The engines have Corliss valve gear. The cylinders are 22 inches and 44 inches in diameter, the stroke being 42 inches. Each main unit is provided with a surface condenser capable of dealing with 60,000 lbs. of steam per hour; a similar condenser, capable of dealing hourly with 24,000 lbs., takes the steam from the auxiliary and exciter sets. Each condenser has a three-throw air pump and centrifugal circulating pump, driven by electric motors. The neighbouring canal provides an ample supply of circulating water. There are two motor-driven boiler feed pumps, each capable of delivering 8000 gallons per hour, and one direct-driven steam pump of twice that capacity.

Steam is furnished by sixteen water-tube boilers, each with 5137 square feet of heating surface, capable of raising 20,000 lbs. of steam per hour at a pressure of 160 lbs. per square inch, provided with superheaters. The boilers are fitted with motor-driven chain grate stokers. Coal is supplied to the stokers from overhead bunkers by two bucket conveyors, which are motor-driven, the conveyors in turn being supplied by automatic means from the outside coal store, over which sidings are run from the Caledonian and North British Railways. The waggons are hauled on the sidings over the bunkers by electric travelling cranes, which dump the coal by lifting up one end of the waggon. The overhead bunkers have a capacity of 2400 tons, and the outside store a capacity of 3000 tons. There is a steel flue for each line of boilers, each being fitted with an economiser. The building is a steel structure, with brick panelling walls; the chimneys, however, are of brick, with terra cotta cornices and facings.

THE YORKSHIRE ELECTRIC POWER COMPANY'S AND THE LANCASHIRE POWER COMPANY'S GENERATING STATION

The arrangement of plant for the Yorkshire Electric Power Company (Fig. 5) is unique, and a short statement of the conditions to be met and the principle involved will be of interest as bearing upon the reasons for the

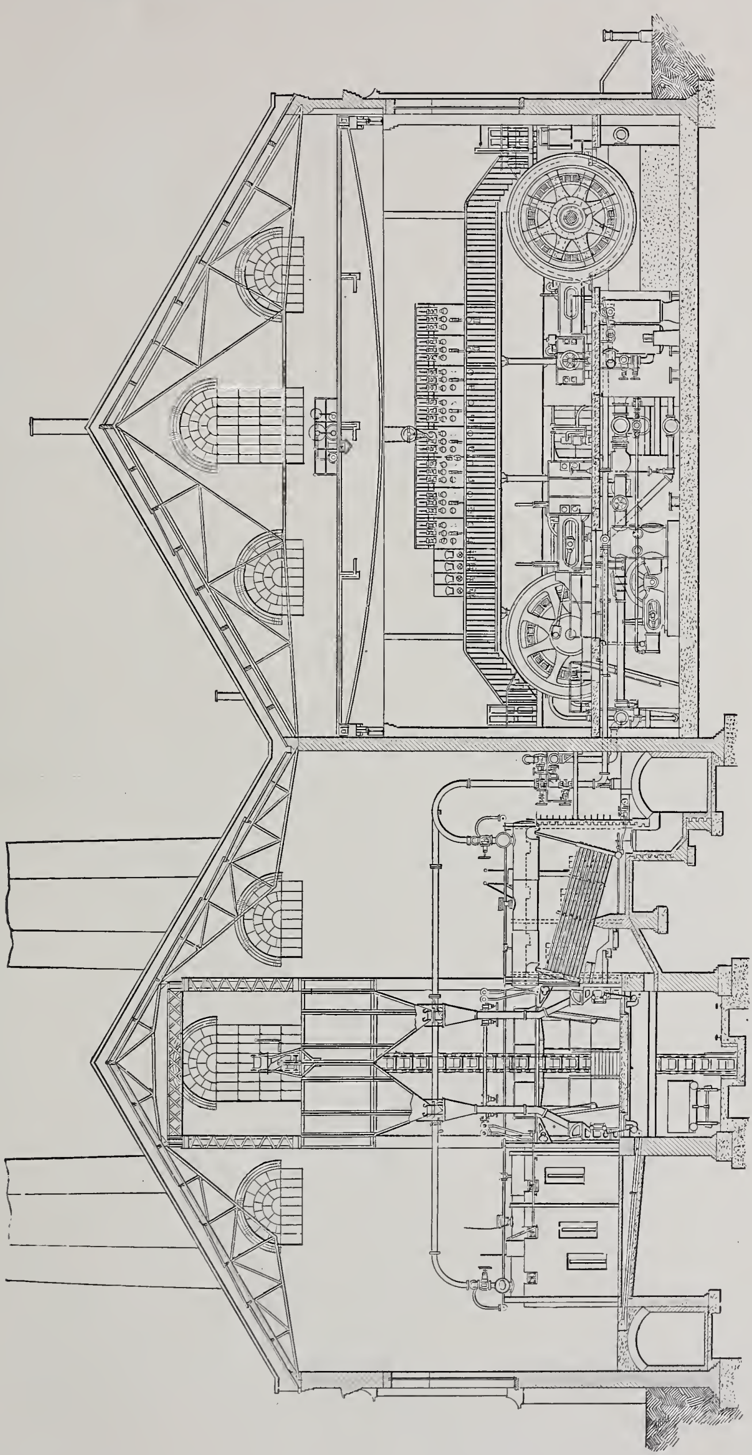


FIG. 3.—THE POWER STATION OF THE CENTRAL LONDON RAILWAY

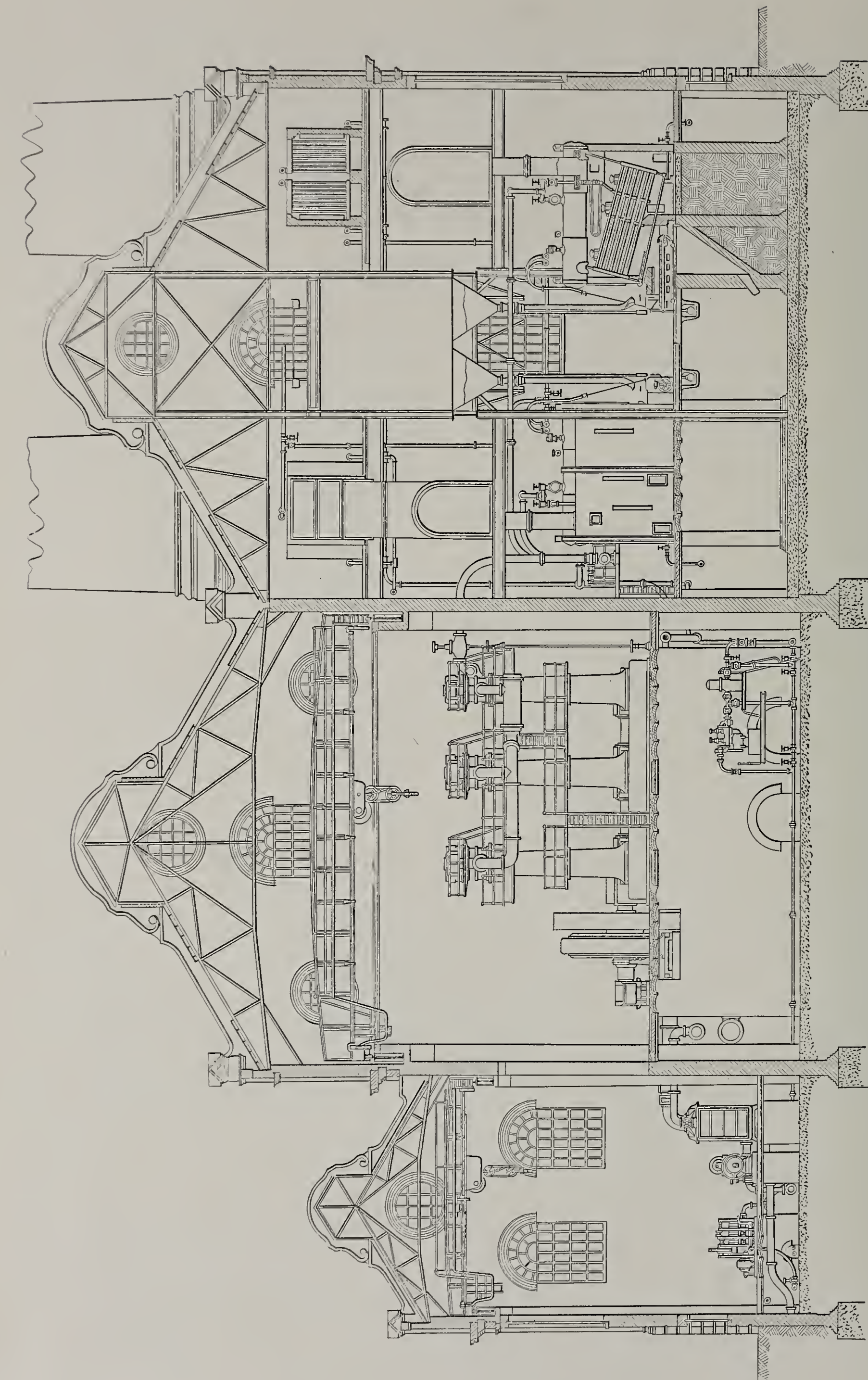


FIG. 4.—THE STATION OF THE GLASGOW CORPORATION TRAMWAYS

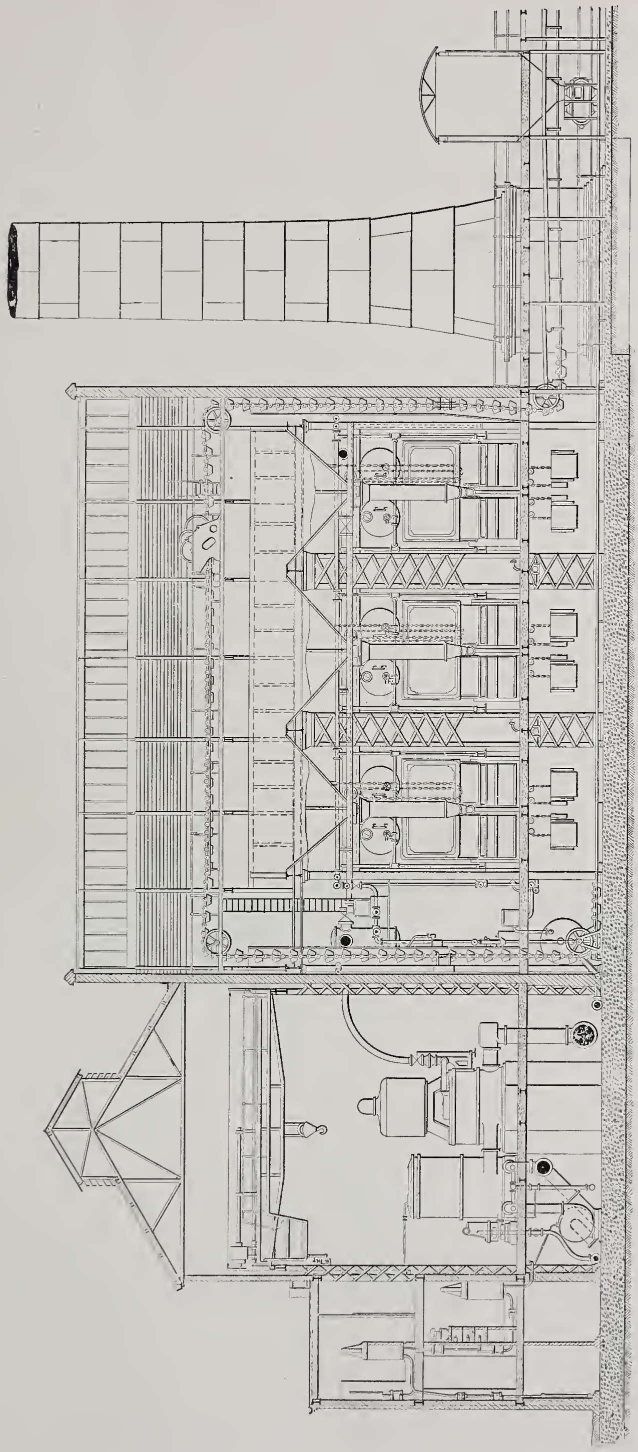


FIG. 5.—THE YORKSHIRE ELECTRIC POWER COMPANY'S STATION

design of this generating station. It should be borne in mind that the only advantage which a power company has over an individual user is in the size of the undertaking, the increased economy of large generating sets, and an improved load factor owing to the diversity in the use of the power. Against this, the power company has to bear the cost of transmission and conversion.

It is evident that since a beginning must be made, and necessarily on a comparatively small scale, the plant of the individual user is comparable with the power company's plant. For this reason economy in capital expenditure is of paramount importance.

The plant consists of four 1500-KW steam turbine sets, making a total plant capacity of 6000 KW. The machinery is arranged in sets of 3000 KW capacity, each set consisting of three boilers and two turbine units, each of 1500 KW, with a condenser, air pump, and circulating pump for each turbine set. A separate chimney is provided for each set of 3000-KW section. By arranging the plant so that each set is self-contained, each addition to the plant bears its own proportionate cost, capital is economised, and a heavy expenditure on account of future developments is avoided.

The first installation which is illustrated in this article consists of two sets of 3000 KW each, forming a block of 6000 KW. When the plant is to be extended, one 3000-KW turbine will take the place of two 1500-KW turbine sets, it having been necessary in the first installment of plant to subdivide the power into four units. Each boiler is fitted with a superheater for 150 degrees of superheat, and chain grate stokers, and will evaporate 20,000 lbs. of steam per hour under a pressure of 160 lbs. per square inch.

The steam turbine set is guaranteed not to use more than 19 lbs. of steam per KW-hour. The condenser has 4500 square feet of cooling surface. The air pump has a capacity of 24,000 cubic feet per hour, and the centrifugal circulating pump will deliver fifty-three times the weight of steam condensed under these conditions; with the barometer at 30 inches, a vacuum in the steam turbine of 28 inches is anticipated.

A new feature, introduced in this plant, consists of an air pump for extracting the air from the circulating system, pipes being connected to points on the circulating system where air is likely to accumulate.

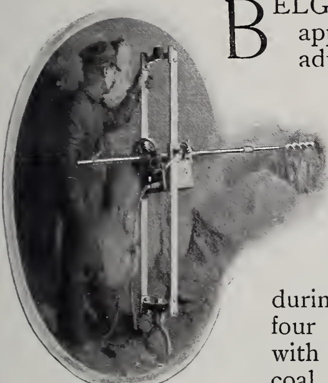
As to the coal handling arrangements, the boiler hoppers are fed from overhead bunkers, the coal passing through weighing machines on its way from the bunkers to the hoppers. The bunkers are filled by a conveyor, which is fed from a hopper outside the boiler room. As the plant is extended, a hopper will be constructed opposite each boiler room, and will be supplied from a railway siding running parallel with the building. The arrangement of sidings, coal storage, and arrangement of plant and design of building is the most economical possible both in capital expenditure and working, under the conditions to be met.

The Lancashire power station is designed on exactly the same lines as the Yorkshire station here illustrated, the requirements and conditions to be fulfilled being the same in each case. But the arrangement for handling the coal is different, owing to the configuration of the ground. The level of the railway is about 70 feet above the basement level, instead of 22 feet, as in the case of the Yorkshire plant. The railway sidings are carried parallel to the building in both cases, and coal is dumped into hoppers located opposite the centre line of each boiler house.

But the relative levels permit filling the overhead bunkers by gravity in the case of the Lancashire station. The operation is effected in this way:—An inclined railway on trestles is laid from the hopper underneath the railway track to the boiler room above the bunkers. The truck travels along the inclined railway by the action of gravity and picks up a counterweight which, as soon as the truck discharges itself, serves to pull back the truck and to give it an impetus which returns it to the filling hopper.

ELECTRIC POWER IN EUROPEAN COLLIERIES

By C. S. Vesey Brown, M. Inst. C. E.



BELGIUM and Germany appear to be furthest advanced among the countries of Continental Europe in theuse of electric power for coal mining, in the development of which much has been done during the past three or four years. Indeed, with the exception of coal cutting by electric power, of which, as far as could be ascertained, there does not appear to be a single example on the Continent, the application of electricity to every operation in coal mining is being carried out to a large extent. Pumping, winding (both for coal and men), ventilating, and hauling are all being slowly adapted, and every day sees further applications in each of these branches of the industry.

In the construction of the generating stations for the supply of power to the motors used in pumping, winding, etc., one sees examples of very fine work on the usual Continental style of elaborate buildings, finished in a pleasing architectural manner both externally and internally, and in the finish and appearance of the station buildings and plant there appears no stint in expense. In a colliery generating station one would hardly expect to see the engine room walls finished with glazed brick or plastered and painted in the same manner as a "show" town station. It seems somewhat incongruous to find this idea carried out in such close proximity to a

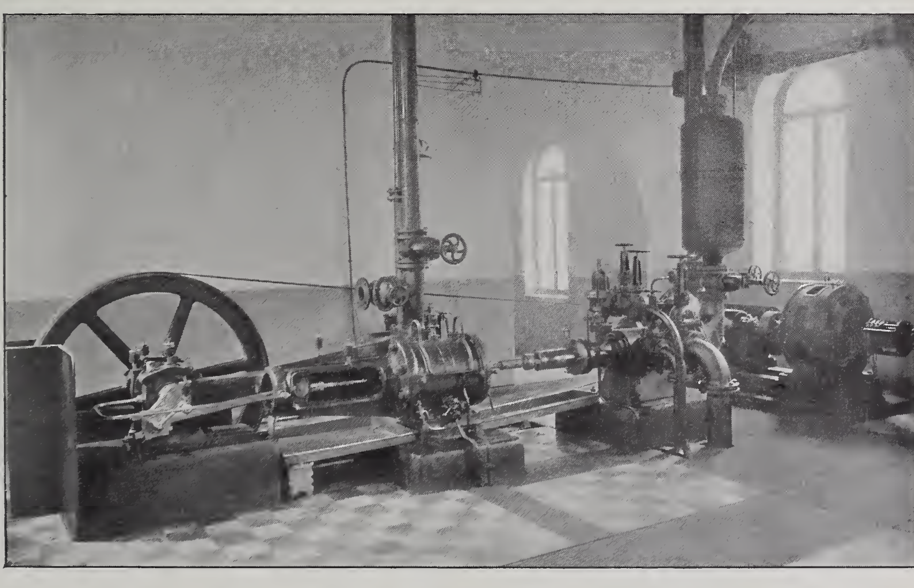


FIG. I.—CONDENSING PLANT AT THE HASARD COLLIERY DRIVEN BY THREE PHASE MOTORS MADE BY THE SOCIÉTÉ INTERNATIONALE D'ELECTRICITÉ, OF LIÉGE BELGIUM

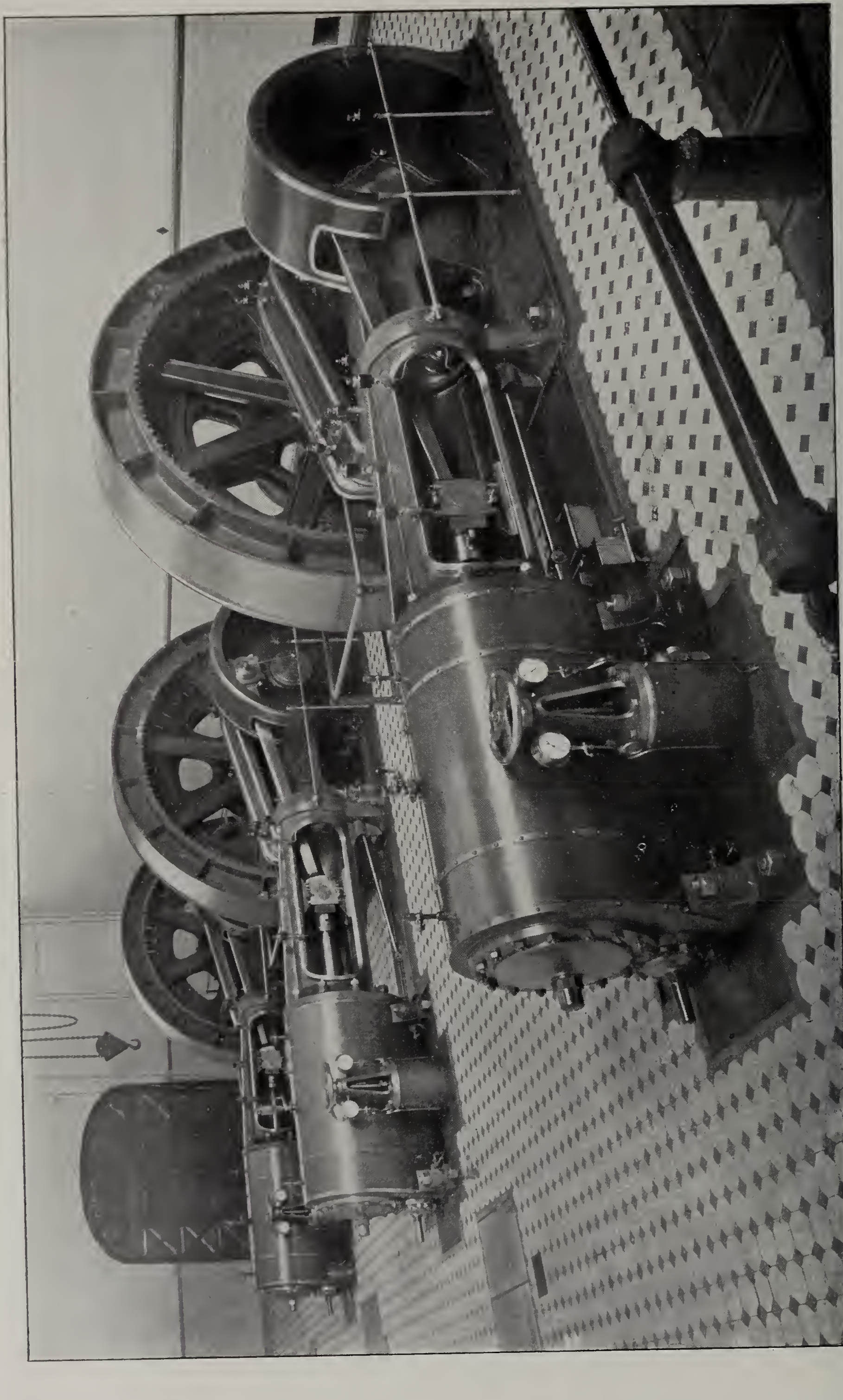


FIG. 2.—A TYPICAL ENGINE ROOM AT A CONTINENTAL COLLIERY. THIS PARTICULAR ONE IS AT THE HASARD COLLIERY, NEAR LIÉGE, BELGIUM. THE THREE-PHASE GENERATORS WERE BUILT BY THE SOCIÉTÉ INTERNATIONALE D'ELECTRICITÉ, OF LIÉGE

coal pit; but it is presumably the wish of the colliery proprietors to have everything in such order that the expense of annual cleaning, to comply with the factory requirements, will be as small as possible.

Much may be said for the principle of building in a substantial and up-to-date manner, as there is no doubt that the risk of failure and derangement of the machinery is minimised if the surroundings are kept clean and free from dust. The general construction of the stations is such as to allow the well-known Continental type of slow-speed, horizontal engines and generators to be installed, though there are a few exceptions to this rule, and some fine examples of vertical engines are to be seen.

Some of the illustrations accompanying this article show typical engine rooms and give a good idea of the style in which these are fitted up. In some of the older plants the size of unit for the generating plant does not exceed 300 kilowatts; but the latest stations contain direct coupled sets of 1000 to 1500 kilowatts, and are capable of supplying both the winding engines and the pumps with power at the same time.

In the near future, no doubt, more use will be made of the combination of coke ovens and gas engine and dynamo sets; but at present there are no notable examples of this latest development in the utilisation of the by-products of coking coal, though there are many examples to be seen of such combinations in the iron works of Belgium and the Alsace and Lorraine provinces.

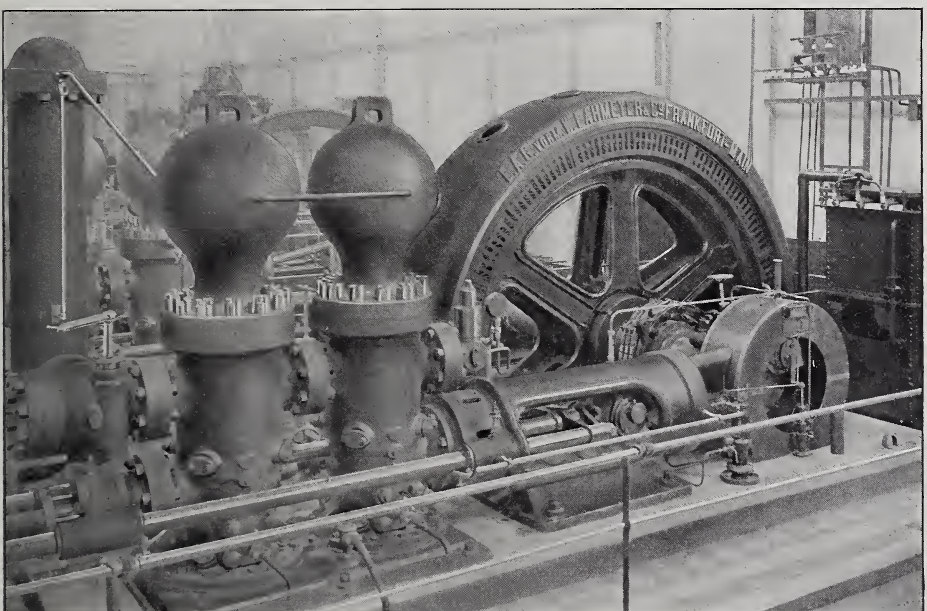


FIG. 3.—HIGH-SPEED PUMPS MADE BY MESSRS. EHRHARDT & SEHMER, OF SAARBRUECKEN, GERMANY, DRIVEN BY A LAHMEYER MOTOR, MADE BY THE ELEKTRIZITÄTS ACTIEN-GESELLSCHAFT, OF FRANKFURT A. MAIN

In the working of a colliery there are no operations more important than those connected with the maintenance of a "dry" pit, and to that end the pumps have in many cases to be kept going day and night, Sunday and week day. The advent of the high-speed pump of the Riedler and other similar patterns has considerably helped the development of electric pumping. The practice is to install these high-speed pumps at the bottom of the shaft, and to force the

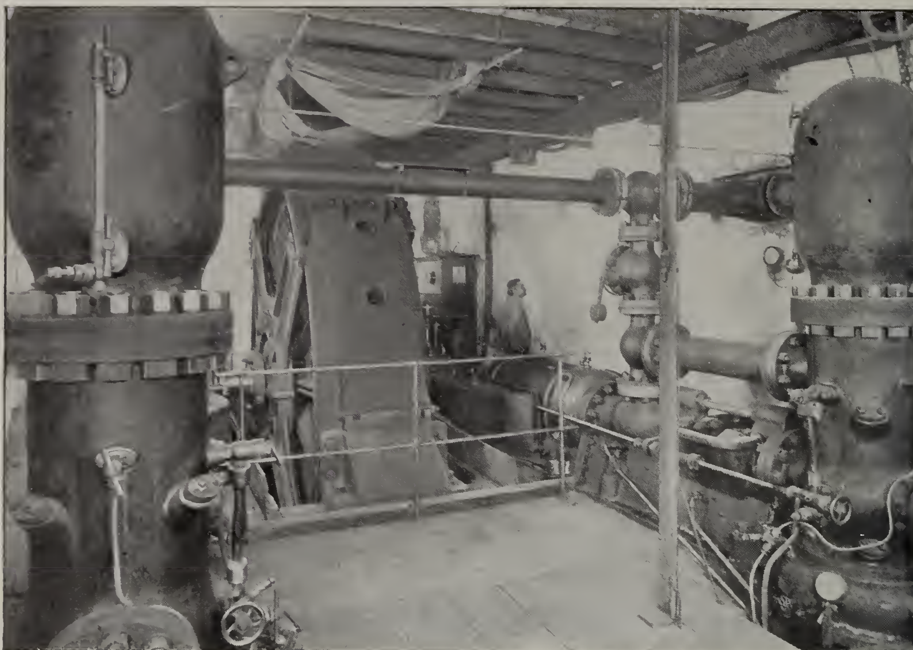


FIG. 4.—PUMPS MADE BY MESSRS. HANIEL & LUEG, OF DUESSELDORF, DRIVEN BY A THREE-PHASE LAHMEYER MOTOR

water to the surface direct from the sump. Several illustrations are shown of this class of pump, which consists of two cylinders placed in the same manner in relation to the motor as the two cylinders of a side-by-side engine with a fly-wheel between the two cranks. The fly-wheel in this case is the rotor of a three-phase motor, and the stator is bolted down to the bed-plate joining the two pump cylinders.

Such a combination is capable of working up to 1000 H. P., and is in many cases supplied with current at 3000 volts. The stator windings are well insulated, and are made to stand the possibility of the bottom part of the wheel race being full of water. The writer has seen such a plant, supplied at 3000 volts, with the rotor only a couple of inches from the surface of the water at the bottom of the race and the lower stator coils completely submerged.

The speed of the pumps varies from 120 to 150 revolutions per minute, and the frequency in most favour is 50 cycles per second, though with the advent of three-phase winding engines there is a tendency to reduce this to 25 cycles, in order to reduce the cost and size of the motors and generating plant and so make the installation of such large-sized plants at the bottom of such deep pits as are found on the Continent a less difficult operation than it is with the larger motors.

The difficulty of lighting the workings with current of such a low frequency as 25 is overcome by the use of motor-generator sets, or in some cases by the use of a small turbine generator driven by some of the water pumped out of the pit and supplied under a head of from 1000 to 2000 feet. This latter arrangement does not involve much waste of water or energy and solves the problem of lighting where the frequency is low, though it has the disadvantage of being dependent on the main pumps.

That there is economy in the use of electrically-driven, high-speed pumps, as compared with the old type of beam engine pump, is borne out by some careful tests made at a Belgian pit where

the two types of pumps are working side by side. For a period of six months the economy in coal consumption averaged over 33 per cent. in favour of the electrically-driven plant, and besides this there was the great advantage of being able to force the electrically-driven pump, by running the plant a little faster, in the event of the water becoming troublesome. The illustrations of some of the pumps shown with this article are typical of what is to be seen in any modern pit, and also of what is being installed in the older pits in place of the beam engine on the surface or the steam pump down below.

Fig. 3 shows a high-speed pump made by Erhardt & Sehmer, driven by a three-phase Lahmeyer motor at 2000 volts and 25 cycles. The pump has plungers 4¼ inches in diameter and a 15-inch stroke. It runs at 146 revolutions per minute, and delivers 450 gallons per minute against a head of 2500 feet. The power absorbed is from 440 to 480 horse-power.

Fig. 4 shows a similar type of pump run at a slower speed and indicating about 300 horse-power when delivering 450 gallons of water per minute against a head of 1600 feet. Electric current in this case is supplied at 2000 volts and 50 cycles.

Fig. 5 shows a pump, made by the Maschinenbau Anstalt Breslau, driven by a Helios motor at 2200 volts and 50 cycles, running at 180 revolutions per minute, delivering 720 gallons of water per minute against a head of 500 feet and absorbing 160 horse-power. Fig. 13 shows another pump put down in one of the Charleroi collieries. The pump is made by Erhardt & Sehmer, and the motor by the Societé Internationale d'Electricité, of Liége. The installation which has been put down to serve this pump also serves pumps in two other pits belonging to the same

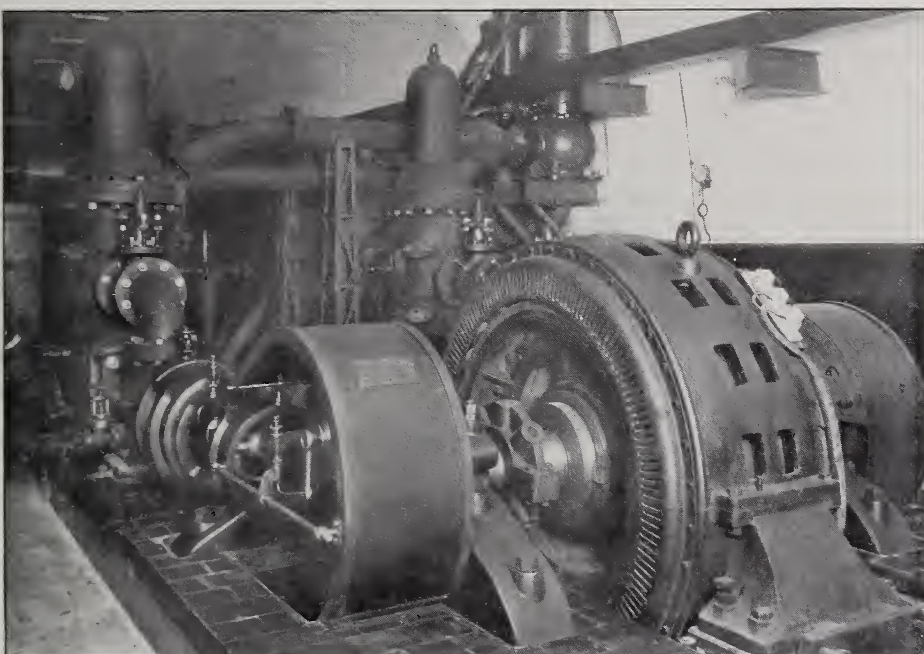


FIG. 5.—HIGH-SPEED PUMPS BUILT BY THE MASCHINENBAU ANSTALT BRESLAU, OF BRESLAU, DRIVEN BY A MOTOR MADE BY THE HELIOS ELEKTRICITAETS AKTIENGESELLSCHAFT, KÖLN-EHRENFELD, GERMANY

FIG. 6.—ONE OF THE ELECTRIC LOCOMOTIVES MADE BY THE ELEKTRIZITAETS ACTIENGESELLSCHAFT, OF FRANKFURT A. MAIN. FOR SURFACE WORK ON COLLIERY SIDINGS

colliery company, and at the same time supplies power to an electric locomotive used for moving the waggons about the pits. It is one of the few cases where the supply of power to several pits is centrally situated, and the results which have been obtained here have prompted other pits to follow the example. The furthest pit supplied is about four and one-half miles distant from the generating station, and power is transmitted by overhead wires at 3000 volts and 50 cycles.

Another pit in the neighbourhood of Liége, the Hasard Mine, is also equipped with a complete electrical installation, and the proprietors propose to follow out the same lines as at Charleroi in dealing with one of their other pits, about two miles distant, where an electrically-driven winding engine is to be put in and the pumps are to be converted to electric driving, all to be supplied from the central station now in use at the Hasard Pit.

This practice naturally leads to economy in working and in labour, as well as saving considerably in the capital outlay, as the proportion of spare plant for one central station is naturally less than that required for two or more stations.

Next to pumping, the most frequent application of electric power is for hauling the coal tubs along the ways at the bottom of the shaft. In those pits where the government allows bare overhead conductors and where there is no danger from gas, it is usual to install an ordinary trolley line and use small electric mining locomotives. These are made in various sizes up to 50 horsepower, and are capable of hauling twenty tubs, with a ton of coal in each tub, at a speed of twenty miles an hour.

Illustrations are given of two of the more modern types of this class of locomotive. A double trolley is sometimes used instead of employing the rails as a return circuit. The track in the latter case is bonded, and a drop of 20 to 30 volts is usually allowed at the end of a line about a mile and a half long. The locomotives are all fitted with double sets of controllers and brakes to allow them to be conveniently run either way. The usual working pressure on the trolley wire is 200 volts, and 6½ feet of

head room are allowed between the rail and the overhead wire.

Where the conditions of the pit do not allow the use of naked wires it is usual to install an ordinary haulage gear for operating either a chain or steel wire rope, the latter being the more frequently adopted.

The introduction of electric power into colliery workings has led, naturally, to the use of electric locomotives on the surface for marshalling the mineral trains within the colliery company's sidings. The pressure of supply and conditions of equipment are similar to those of the ordinary trolley road.

The most interesting and the latest development in the application of electrical power in coal mining is that involved in the winding gear for drawing coal and men from the workings. The subject is, perhaps, all the more interesting on account of the extremely varying conditions which are imposed upon a winding engine, and also on account of the splendid service which the steam winding engine gives. Practically all the larger electrical manufacturers on the Continent have installations of electrically-driven winding engines at work, and each one is interesting to those who are considering the question of installing a new plant or who are making extensive alterations. It is certainly well worth the consideration of a colliery manager who has to sink a new shaft or to alter the winding gear on an old one to investigate the advantages of electrical winding gear. It is, perhaps, too early yet to say to what extent there is economy in using electricity, as compared with steam, but the tendency in all new work on the Continent is undoubtedly towards the installation of electrical gear.

The practice is nearly all in the direc-

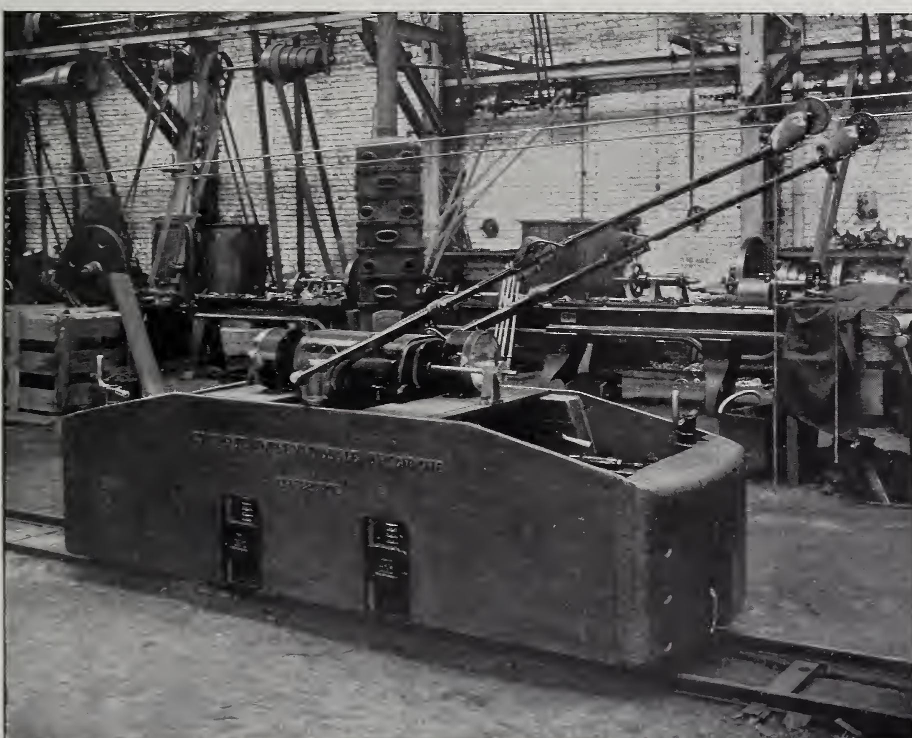


FIG. 7.—A DOUBLE-TROLLEY ELECTRIC MINE LOCOMOTIVE MADE BY THE SOCIÉTÉ INTERNATIONALE D'ELECTRICITÉ, OF LIÉGE

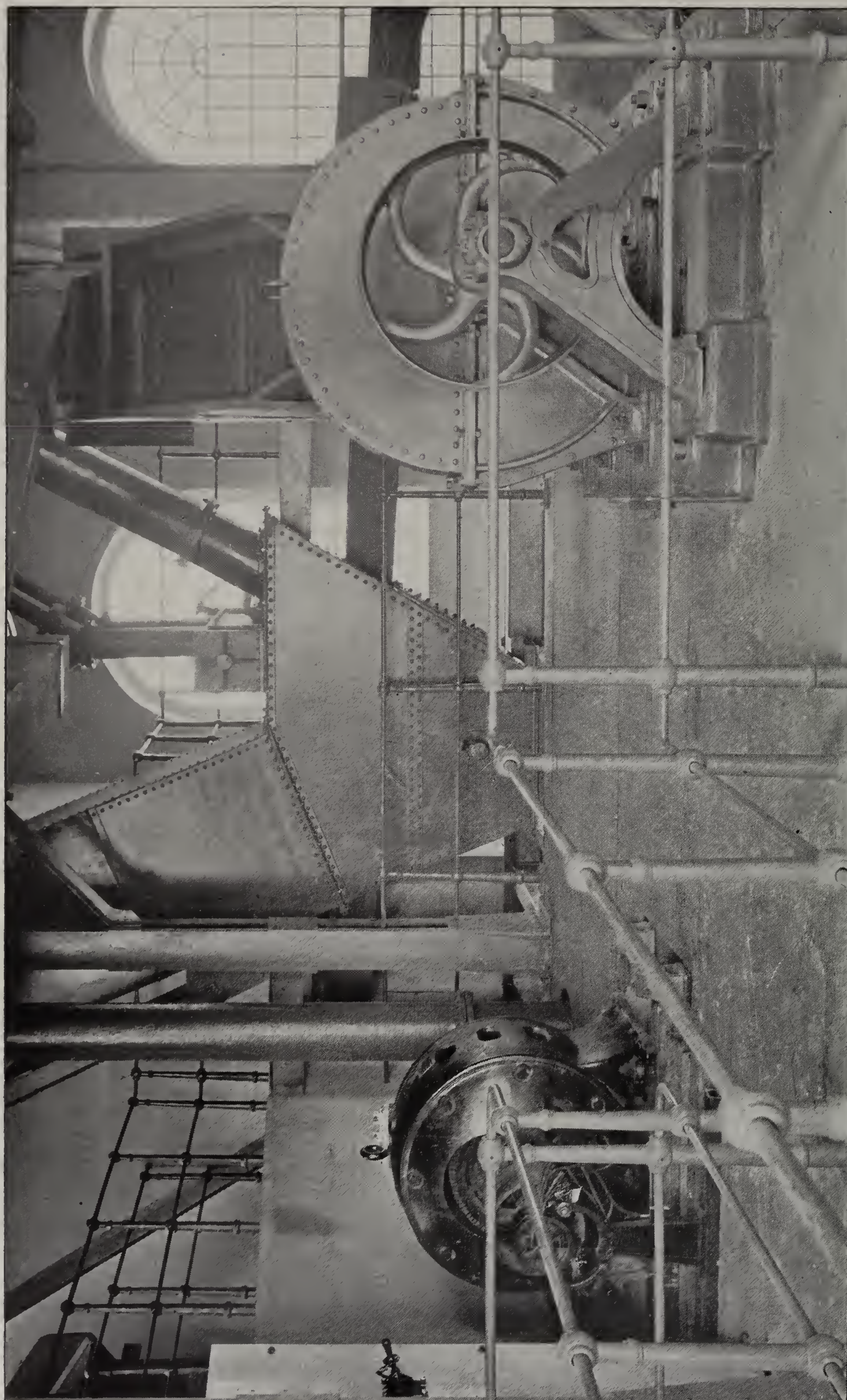


FIG. 8.—ELECTRIC DRIVING OF A COAL WASHING PLANT AT THE SCHARNHORST COLLIERY

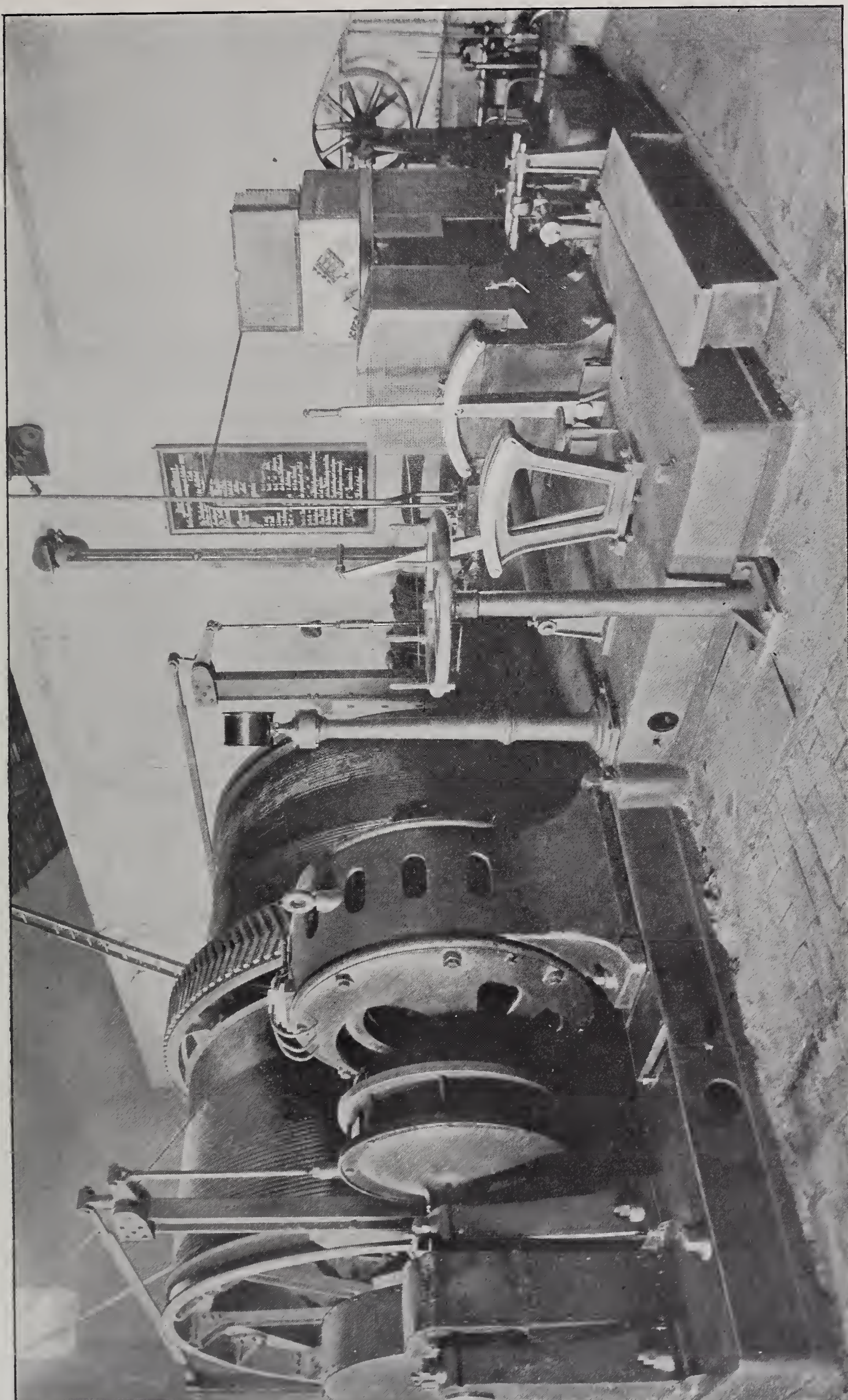


FIG. 9.—ELECTRICALLY DRIVEN WINDING GEAR AT THE GERMANIA COLLIERY. THE THREE-PHASE MOTOR HERE USED WAS SUPPLIED BY THE HELIOS COMPANY, OF KOLN-EHRENFELD

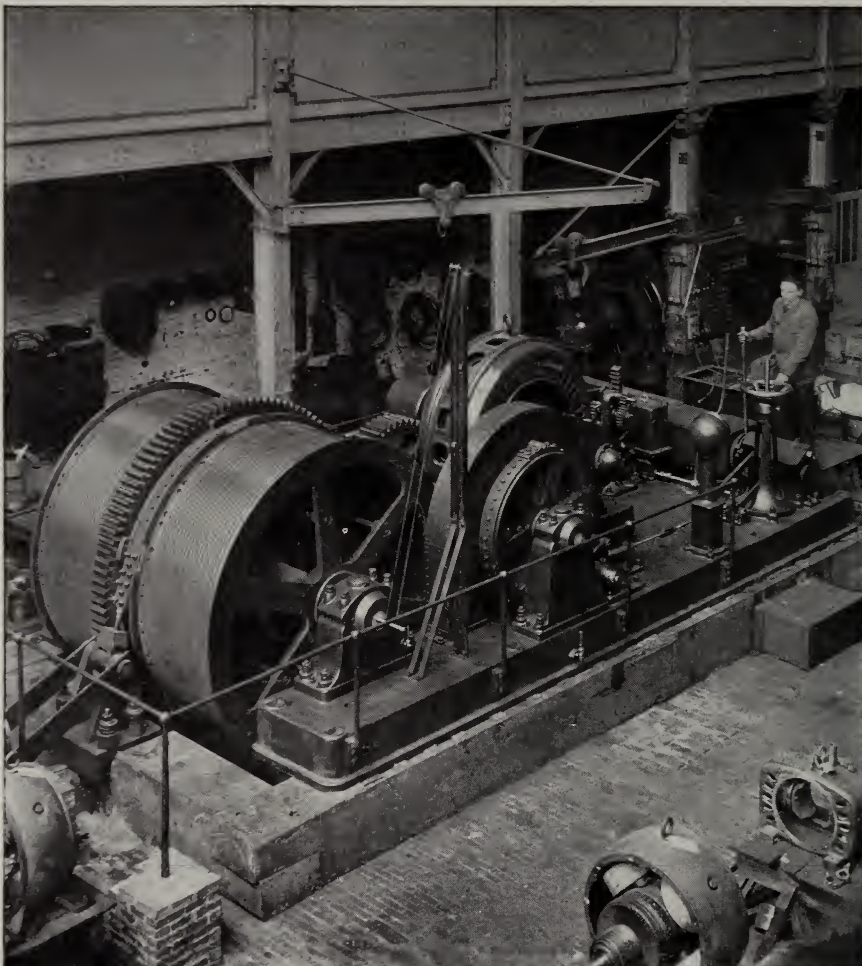


FIG. 10.—A MOTOR MADE BY THE SOCIÉTÉ INTERNATIONALE D'ELECTRICITE DRIVING A WINDING ENGINE AT A COLLIERY NEAR CHARLEROI

tion of three-phase current, the motors in some cases being direct-connected and in others driving through helical gearing.

The Helios Company, of Köln, have installed in the Germania mine, near Essen, a winding engine on this principle. It is capable of drawing two tons of coal per lift from a depth of 1400 feet at a speed of 10 feet per second. The power absorbed by the motor for this work is 120 horse-power, and is supplied at 2000 volts, 50 cycles, from the central station, about one and three-quarter miles distant. The arrangements for operating the motor are simple, and the usual automatic devices are installed for preventing overwinding and failure of the current. As will be seen from Fig. 9, the attendant has to operate two levers, the right hand one being the starting, stopping and braking lever and the left hand one being the reversing lever. The installation at this mine consists of two horizontal, 375 KW, three phase, steam generators supplying current at 2100 to 2300 volts to a 160 horse-power pump, and a 400 horse-power ventilating fan, besides the winding engine and the small motors

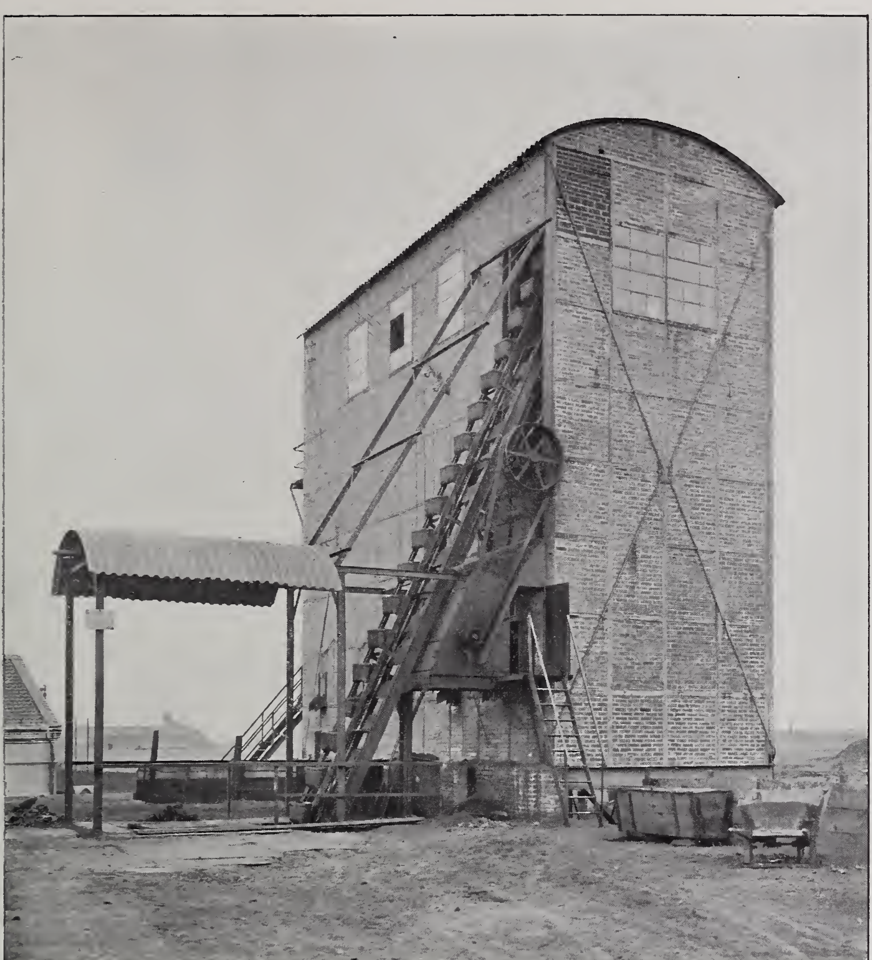


FIG. II.—A HELIOS MOTOR DRIVING A COAL ELEVATOR AT THE GERMANIA COLLIERY, NEAR ESSEN, GERMANY

and electric lights used in the workshops.

The utility of electric winding and hauling engines for colliery working cannot be better shown than by the two examples of work done by the Lahmeyer Company, of Frankfort, and the Société Internationale d'Electricité, of Liége. It is well known that the dip of the coal mines, in many localities, suddenly alters, and it is in such cases necessary to sink perhaps several short shafts to work the coal seams economically. By the use of a light electric winding engine placed to operate over one of these auxiliary shafts and supplied with power from the central station on the surface, all necessity for steam boilers is dispensed with and the attendance is reduced to a minimum.

In the Nöel-Sart-Culpart mine, near Charleroi, the coal dips at an angle of 30 degrees to the south, and two main shafts are sunk to a depth of about 1600 feet. At the end of a long road half a mile from the bottom of the shaft an electrically-driven winding engine is installed, which is supplied with three-phase current at 1000 volts and 50 cycles. The motor is capable of work-

FIG. 12.—AN ELECTRICALLY DRIVEN COKE PUSHER

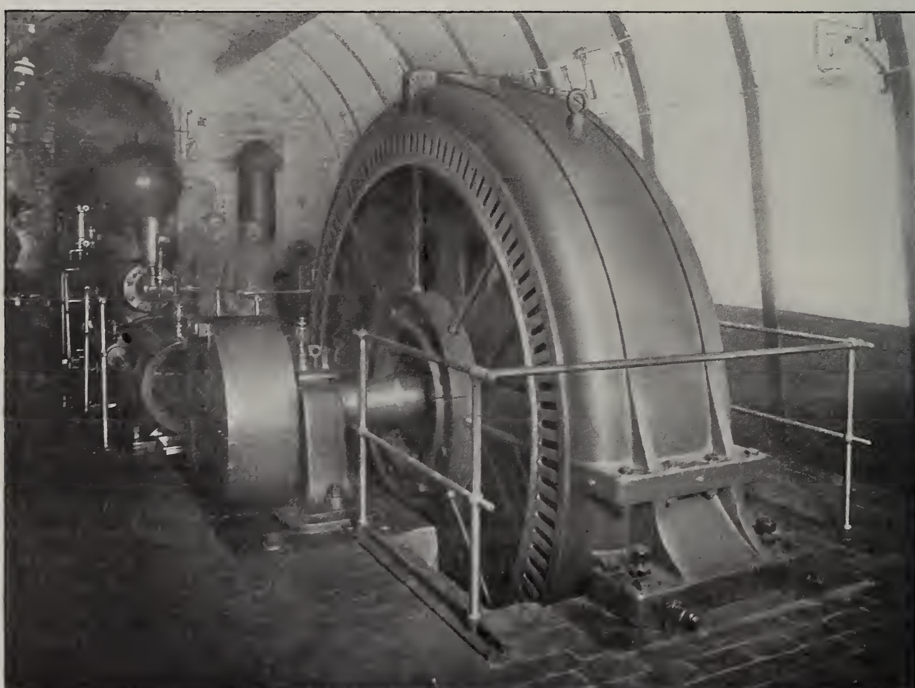


FIG. 13.—ELECTRICALLY DRIVEN PUMPS AT THE GILLY MINE, NEAR CHARLEROI. THE MOTOR WAS MADE BY THE SOCIÉTÉ INTERNATIONALE D'ELECTRICITÉ, LIÉGE, BELGIUM

ing up to 300 horse-power, and averages 125 horse-power. The weight of coal per lift is about one and one-half to two tons, and the lift is 420 feet, the speed averaging 12 feet per second, with a maximum of 17 feet per second.

While the general tendency is towards three-phase apparatus, there are a few examples of continuous-current motors at work as winding engines.

The smaller types of winding and hauling gear for light loads and for short lifts or drifts are driven by continuous-current motors in a number of pits, especially where continuous-current generating plants were installed eight or ten years ago for the small three-throw pumps and other uses. These generally are shunt-wound motors supplied at 440 to 500 volts.

Artificial ventilation has received a certain amount of attention, and there are several cases where steam driving of fans has been entirely displaced by electric motors.

The introduction of electricity for pumping purposes naturally led to its adoption in other parts of the colliery, and coal washing plants and screens are thus now operated by electric motors. The power varies from 40 H. P. to 100 H. P., depending upon the work to be done. At the Recklinghausen pit of the Harpener Coal Company, near Dortmund, the Allgemeine Electricitäts Gesellschaft, of Berlin, have erected a complete electrical equipment for the whole of the colliery work, with the exception of winding, and the only steam engines at work are the winding engines and the engines driving the three-phase generators in the colliery company's central station. All of the pumping, underground haulage, screening, washing and lighting plant is supplied from this central station at 1000

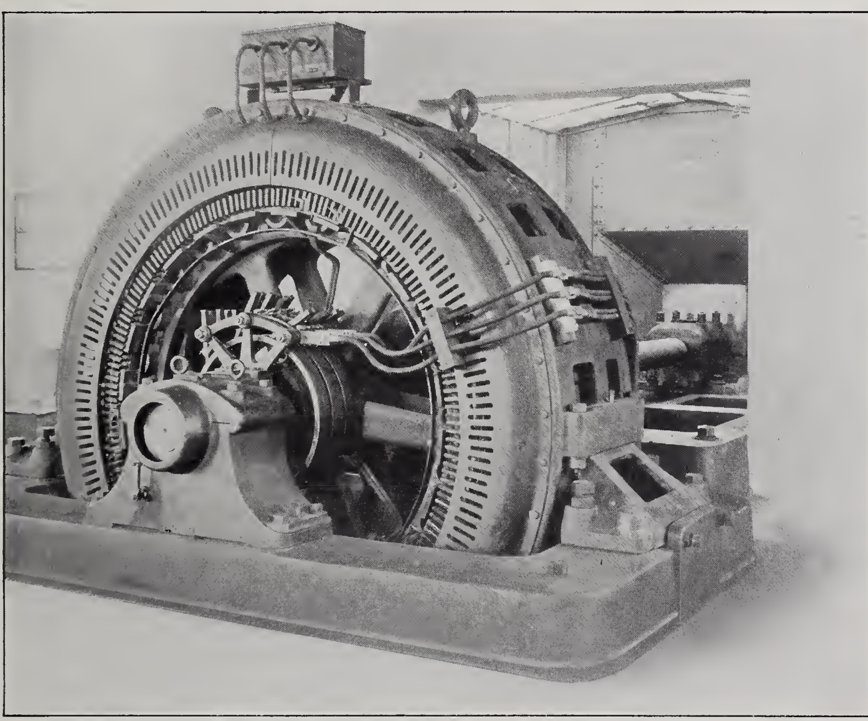


FIG. 14.—A 400 H. P. THREE-PHASE MOTOR AT THE GERMANIA MINE DRIVING A VENTILATING FAN. MADE BY THE HELIOS COMPANY

volts direct to the motors. As stated before, similar plants are at work in Belgium and other parts of Germany.

It is the general practice on the Continent to combine with the coal mine some other business, such as the making of coke and the recovery of the by-products, or the manufacture of briquettes, fire-bricks, etc. In fact, it would be a difficult thing to find a colliery where the sole business is the extraction of coal, and in connection with these extraneous trades the use of electricity is rapidly extending.

An illustration is given in Fig. 12 of a coke oven charging machine. This receives its power through a double trolley wire stretched in front of, and parallel to, the coke ovens, and the machine travels on a set of rails in front of them. It is arranged to deal with the removal of the coke from each oven by means of a heavy iron shield made nearly the same size as the oven and fixed on the end of a long toothed rod, which is worked backwards and forwards through a reduction gear by a series-wound motor. The controller is similar to that of a tramway motor. The same motor operates the travelling gear of the machine up and down in front of the ovens.

In concluding this short account of the development of electrical work in connection with collieries on the Continent, acknowledgment must be made of the facilities which the different firms mentioned have placed at the disposal of the writer to compile the information set forth. Only a very few examples have here been shown, but even these are sufficient to show that the application of electrical power in Continental colliery working has progressed rapidly during the last few years.

FINIS

PHOTO BY FALK, NEW YORK

JOHN W. LIEB, JR.

PRESIDENT-ELECT OF THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

SEE PAGE 343

CASSIER'S MAGAZINE

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HAULING ORE FROM MINE TO RAILWAY

NEW GOLD FIELDS IN THE UNITED STATES

By Day Allen Willey

THE quantity of precious metal which remains to be obtained in the United States has been a problem which the scientist as well as the fortune-hunter has been trying to solve since it became known that the streams of California flowed over what the poet has termed "golden sands." The problem has not been solved to this day,—probably never will be; but the quantity of gold and silver which is being taken out of the earth indicates that this resource is far from being exhausted, and that the future of the industry in America promises great possibilities. This prediction is verified by the product of the mines in the various states and territories.

During the year 1903 the director of the United States Mint estimates that fully 3,600,000 ounces of gold and 56,500,000 ounces of silver were obtained, including the Nome and other fields in Alaska outside of the Klondike. This amounted to fully 25 per cent. of the world's production of gold and 33 per cent. of the world's production of silver. In 1895 the various states and territories produced but 2,255,000 ounces of gold, although the production

AN EXPERIMENTAL SHAFT. GETTING OUT ORE FOR ASSAYING

of silver nearly equalled that of 1903, being 55,727,000 ounces. Consequently, the yield of gold has increased nearly 60 per cent. in the last decade.

Colorado can be called the treasure house of America, since from it came over 1,000,000 ounces of gold last year and about 14,000,000 ounces of silver, its gold production being over three times as great as that of any other state or territory except California, including the portion of Alaska not in the Klondike. California still maintains second place in the series of gold fields, with about 800,000 ounces, although it has declined to the extent of 18,000 ounces since 1902. The hills of South Dakota produced 333,000 ounces, about the same as the territory of Alaska, while Utah produced 245,000, Arizona 231,000, Montana 200,000, and Nevada 173,000.

THE MAIN STREET IN TONOPAH

Taking the principal gold-producing states and territories separately, it is an interesting fact that all show a notable increase compared with 1895. As might be expected, the territory of Alaska is now yielding over four times as much as in 1895. It is somewhat surprising, however, to note that Arizona has more than doubled its production, Oregon's is a third greater, that of South Dakota has nearly doubled, and that of Utah has nearly quadrupled, for in 1895 only 66,500 ounces were taken from the Utah ore beds. It is needless to say that the depreciation of the value of silver has caused its production to be neglected, and has undoubtedly proved a stimulus to gold mining; but the output of the last decade shows that it has not diminished in any one year over 5 per cent., reckoned on the yield of 1903. The smallest annual quantity obtained since 1895 has been 53,860,000 ounces.

A study of the principal gold fields show that the increase is largely due to two factors. The promoters of the mining industry have to thank science for the development of processes by which both of the precious metals referred to can now be secured from ores which in the past contained such a small proportion that they were thrown away as worthless in the form of tailings. It may be said here that the degree to which the chlorination and cyanide processes has been perfected has allowed the miner to obtain gold held in the form of sulphurets and other refractory ores

A HILL-SIDE CLAIM

to such an extent that in recent years some of the mines have increased their output over 50 per cent. An illustration of the economy attending the treatment is given in one operation in the west where the ores are noted for the small quantity of gold contained in them. It actually saves 95 per cent. of the pure metal.

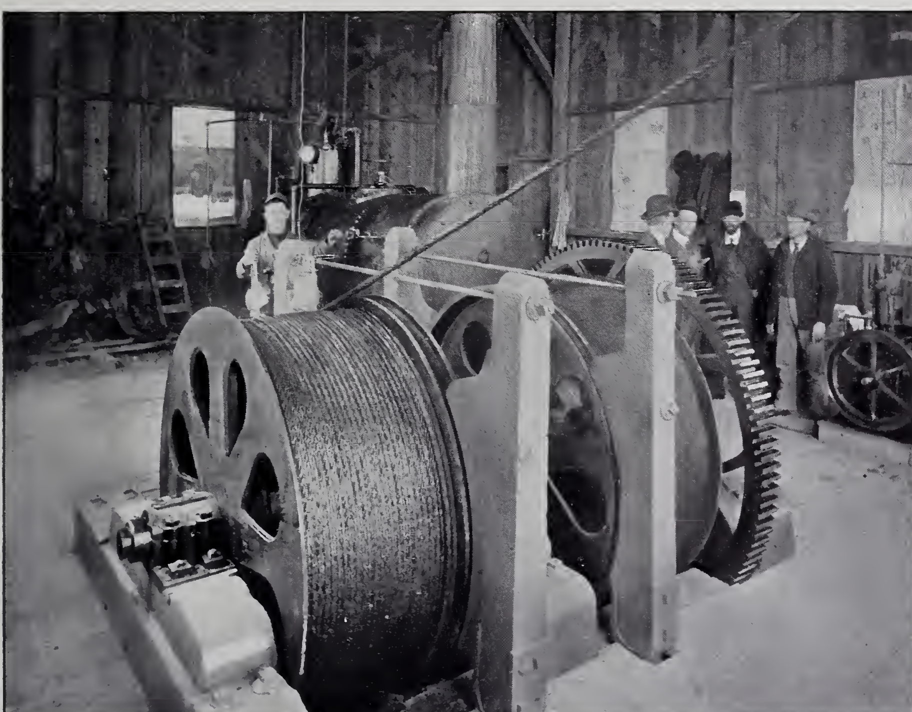
A very large percentage of the increase in recent years has, however, come from deposits which have hitherto been unknown or whose extent has been overlooked. In this respect it may be said that the history of the industry in the United States is continually repeating itself. It is the unexpected that often happens in making rich discoveries. This is just as true of the latest fields which have been exploited as of those which formed the "strikes" of a quarter of a century ago.

Every state and territory in which gold and silver has been found in any quantity has its stories of discoveries which, while they seem like romances when told, are examples of the adage that truth is stranger than fiction. Montana furnishes several of the more interesting. Every prospector in the Rocky Mountains has probably heard the tale of how Tom Cruise discovered the great Drum Lomond mine. For years the old miner had been sluicing out the gold in the bed of a creek a few miles from Helena. Some days he secured less than a dollar's worth, and other days five times as much. The uncertainty was discouraging, but he had experience enough to know that the ledge from which the gold had been washed must be somewhere in the vicinity, so he explored the valley, but without result. Then he climbed the sides for hundreds of feet. At last he saw a projection which was apparently rock covered with earth and leaves. A few digs with the shovel laid bare the outcropping of the ore vein which was to become one of the most famous in the world.

Montana also contains the Granite Mountain mine, which was supposed to consist of surface ore. The shrewd

superintendent noted indications which led him to believe another ore body lay beneath. The mine owners, however, disagreed with him, and he began investigating for himself when the veins appeared to be exhausted. On the very day he received a telegram to abandon the claim he made the discovery of the lode beneath. The telegram he sent his employers caused them to give him *carte blanche* in the way of spending their money to reach the ore. It is a matter of history that the wealth of this mine has erected some of the finest buildings in St. Louis, where the owners invested their profits.

In the long list of accidental discoveries which have made fortunes either for the discoverers or others to whom they divulged their secret, that of Park City will always occupy a prominent place. It was not always termed Park City, and many of the miners in Utah to this day still call it Parley's Park, its original name. Sitting on a ledge of rock to rest while travelling through this region, a prospector began knocking away at the surface with his pick, without thought that its point was entering a mass of silver ore which has since been mined for over ten years. Noting the glitter of the fragments, he took them to the nearest town and had them assayed, more out of curiosity than otherwise, for apparently they contained too much of the white metal for it to be genuine. The assay showed no less than twelve pounds of silver to the ton. News of the discovery soon spread and openings were made from which ore yielding over 3,000,000 pounds of pure silver has thus far been taken, and no one knows how much more lies in the bowels of the hills.



A TYPICAL MINE HOIST

Such are instances of mines which have not been exhausted since they were opened. There are darker chapters in the history of the western gold fields;

SACKING GOLD AND SILVER ORE FOR SHIPMENT TO THE SMELTER. LOOSE ORE IS SHOWN PILED UP AT THE LEFT

for example, Treasure Hill, situated in Nevada, the state which the Comstock lode has given such a reputation. Nearly a half century ago the ore from fully a hundred openings in the mountain side on which it stands was brought to Treasure Hill, making it one of the richest, and, for the time, one of the most active communities in the west. Companies were formed by the score to secure the deposits of precious metal.

Then came the day when the pioneer miners, cutting into the hillside, found the veins were "pinched." They began selling out stock in companies in which they were interested. As quickly as when the veins were discovered the announcement spread that the end of the ore was in sight. A panic followed, and Treasure Hill was deserted. Possibly its hotels, stores and dwellings are standing yet. A few years ago a traveller chanced through the place and saw glasses and bottles on the bars of the saloons, cues and balls on the billiard tables in the hotels, row after row of dwellings, some with doors open, but not a human being was visible.

Yet the day may come when some prospector will again explore the shafts and tunnels, and perhaps, with a few blows of his pick, will open up another source of wealth as great as that which built the city. The history of the Comstock lode proves that this is not impossible. This great group of mines has, perhaps, had as many ups and downs since the first shovelful of ore was taken out of the earth as any in the world. Its valuation in the stock market shows how it has been regarded.

James G. Fair discovered a mass of ore in 1875 when people were leaving the town by hundreds, just as they had deserted Treasure Hill, and empty houses were being bought to be torn to pieces for firewood. Then came the bonanza announcement, and in a short time the value of the property was estimated at no less than a hundred million dollars. Within twenty-five years it had shrunk to less than $2,000,000. Last year the value of the metal it produced was about $1,500,000. Still another mass of ore may be discovered any day which will again increase its value ten-fold or twenty-fold, although the most optimistic dare not predict that the discovery which Fair made—purely by accident—will ever be equalled, for the ore extended no less than 1300 feet in length, while its width was over 500 feet, every ton worth at least $1000.

But Nevada contains much more wealth, as yet hidden beneath its surface. This is verified by the fact that within its borders has been made the most notable discovery of gold and silver ores recorded since the resources of Alaska became known to the outside world. In May, 1900, James L. Butler, at that time District Attorney of Nye County, left Belmont, the county seat, to prospect in the mountains to the southward. Before his departure he confided his intention to his friend, T. L. Oddie, a mining man, of Belmont. With his outfit packed on the back of six burros, he started from Belmont, passed over the Manhattan Mountains, travelled all day, and camped at nightfall at a spring known to the Indians as "Tonopah," meaning "water near the surface."

While encamped at this spring Butler made the discovery which caused "Tonopah" to become known throughout the country. He found numerous croppings of black, fine-grained quartz, showing a large quantity of gold,—so much, in fact, that he was deceived as to its value, doubting it to be genuine. He took several samples, in all about 75 pounds of ore, and proceeded to Belmont. There assays were made which ran from $80 to $600 to the ton. The discoverer returned to Tonopah, accompanied by his wife, and located several claims. He asked his wife to name one, which she did, calling it "Mizpah." The first ore taken out amounted to two tons, containing so much silver that after paying the expense of mining, hauling it 150 miles to the railroad, the freight by rail to the nearest smelter, and the cost of smelting, Butler and his friends received $600 profit.

During the fall of 1900 the news reached the outside world that a "strike" had been made at Tonopah,

THE MIZPAH CLAIM IN THE TONOPAH DISTRICT

and during the winter a number of men came into the camp from Carson, Reno, and other points. Butler and his associates decided to lease some of their property. On the most productive lease the first body of ore struck was 5 feet in width, 80 feet in depth, and 60 feet in length, and assayed from $150 to $500 a ton. This lease produced 3500 tons of ore, averaging in value more than $100 a ton. After its expiration Lynch & O'Meara, the lessees, took a contract to sink the first shaft in the Mizpah claim. In seven months they took out about 4000 tons of the same average value as that taken out under the lease. In a little over a year they cleared half a million dollars, after paying all expenses.

This brief outline of the beginning of Tonopah is worth noting, for it is admitted to be the most valuable of the newer fields in which precious metal has been discovered in the United States. The nucleus of the field consists of the eight original claims which were sold by the discoverers to eastern capitalists. Each claim is 4500 feet in length by 600 feet in width, the eight adjoining one another. Their area is very small in comparison to some of the other operations in the country, but the extent and quality of the deposits have naturally caused prospectors to distribute themselves over the adjacent territory for a considerable distance around. The principal ledge of the original group is the Mizpah.

One tunnel, 1650 feet long, which has been excavated at a depth 300 feet from the surface, penetrates the ore for its entire length. Measurements made in this tunnel show the existence of a ledge which ranges from 5 to 18 feet in width. Assays made by the United States authorities of samples of ore taken from the Mizpah show a minimum value of $100 a ton in silver. These figures are based upon investigation made by representatives of the government.

Various estimates have been made of the wealth of the original group, and, as usual in the case of new fields, some very exaggerated statements have been given out; but, as already intimated, operations have progressed far enough to convince the government experts who have examined the region that it is unquestionably the richest in silver and gold which has been discovered in recent years.

Mining operations have progressed to such an extent in the Tonopah field that at present fully 100 hoisting plants have been erected. Since the discovery about 25,000 tons of ore have been reduced to a bullion value of nearly $4,000,000, of which about two-thirds is silver and the balance gold. As yet most of the ore has been taken from the surface, and the bulk of it is being stored, awaiting the erection of reduction works ample to treat the output, for the expense of extracting the metal at present is very large, owing to the distance which the ore must be shipped in order to be treated by the reduction works. In some cases it has been sent as far as San Francisco, at a cost of over $50 per ton for transportation. Two mills, however, have been completed in the field, and another large one is being erected, so that in the near future the gold and silver can be secured at a minimum outlay directly at the mine openings. The discovery has resulted in the creation of a city of 5000 population, named after the field, and the actual investment of $10,000,000 at least in the mining property, reduction works thus far completed and other enterprises.

Next to Tonopah the most interesting of the new fields is located in Idaho. It is known as the Thunder Mountain district, taking its name from the mountain from which a large proportion of the metal has thus far been secured. It differs from Tonopah in the fact that placer mining was carried on for a considerable period before experts discovered that most of the metal was combined with quartz. It was not until 1901 that a large body of quartz was accidentally found. The assays produced such results that since then the placers have been neglected, and not only the older companies, but several new ones, have begun working the lode on a very extensive scale.

The operations in the quartz, however, were so small as to be only experimental until 1902. While the deposit has not as yet been completely traced, an investigation made by government officials warrants the belief that it is very extensive. As in the case of some other rich mines, the Thunder Mountain is almost inaccessible. During the first year all of the machinery and other equipment had to be hauled a distance of seventy miles over rough mountain roads in order to reach it, and its isolation has undoubtedly been one reason why it has not become a centre of more interest.

The discovery of the lode at Thunder Mountain calls attention to the wide area of territory in the state of Idaho alone, about which very little is yet known. While it has been producing placer gold for over forty years, the richest deposits thus far discovered have been worked out, and the majority of the miners who had worked them have gone into other parts of the country in quest of new fields. As but a very small mileage of railroads has thus far been constructed in Idaho, prospecting is attended with far more difficulty than in many other states noted for their mineral resources.

Naturally, the Thunder Mountain discovery has renewed interest in Idaho, but the principal prospecting is being done in the vicinity of the mines thus far opened. In what is known as the Big Creek region are indications of very extensive mineral deposits, according to the report of the United States assayer of Idaho. Within a few miles of Boise City experimental openings are being made upon land which until recently was used for sheep ranches, but from which specimens of gold ore of high quality have been taken. It is also believed that extensive placer deposits remaining to be worked, especially along the beds of the Snake and Clear Water rivers, as these streams have never been thoroughly explored by mineral experts.

There has never been an investigation covering the entire mineral belt west of the Mississippi River, except that of the United States Geological Survey; but that examination has been general, and has not been confined merely to gold and silver. That a very extensive portion of the west is comparatively unknown, so far as its hidden resources are

A PROSPECTING PARTY

DINNER HOUR IN A PROSPECTOR'S CAMP

concerned, is verified by United States assayers located here and there in the mining regions, and other impartial authorities.

In addition to Idaho, much of New Mexico remains to be covered, although in that state is located the Oritz mine, reputed as being the oldest gold lode mine in the United States, and one which has produced many millions of dollars in value. It is still being operated at a profit, although on a smaller scale than originally. Socorro county, which has a greater area than the entire state of Massachusetts, contains not only gold and silver, but also copper; but thus far only a small section of it has been thoroughly examined.

Washington produced but 21,000 ounces of gold in 1903. This is a large amount, when the comparatively few openings which have been made in this state are noted. In fact, that State presents some of the greatest possibilities for mineral production of any part of North America. In Northwest Washington the deposits contained in Mount Baker are at last being opened. There one ledge has been found which has been traced to a distance of 300 feet, and in some places is 500 feet in width, although its thickness varies greatly. The ledge has been tunneled to a depth of 280 feet, all of which is adjacent to the ore. This district is also one of the most inaccessible in the country, which accounts for the fact that operations on an extensive scale have only begun within the last year.

In Snohomish County the mines now being worked were unknown until about ten years ago, and for several years nothing was done in the way of getting out the ore; but machinery has been installed of such quality that over 90 per cent. of the metal is being secured. One company alone has completed 10,000 feet of tunnels and shafts, owing to the extent of the ledges which it has reached. There, again, only a small section of the county supposed to contain minerals has been opened up.

Of the mining possibilities of Wyoming it has been said that their promise is so great that one is at a loss to understand why development has been so long

delayed. It is a fact that although mining has been in progress for a number of years, the industry is still in an experimental stage, and up to this time there is not a mine in Wyoming which can be considered thoroughly developed. It is doubtful if a shaft has been sunk by any of the companies to a depth of over 300 feet, and the majority of openings are less than 250 feet, for the reason that the workable veins have been found so near the surface. While no bonanzas have been discovered, assays of ore from mines located in various portions of the state show that they contain gold values ranging from $6 to $45 a ton. Near Hecla ore has been found which paid as high as $200 a ton. Thus far the larger companies have confined their development to three of the southern counties.

Though the southern states contain the oldest gold mines of the original United States, and these deposits furnished all of the gold produced between 1804 and 1828, less attention has been paid by prospectors to this section of the country, considering the area where ore has been found, than probably to any other gold field. As a matter of fact, it is one of the most extensive, reaching as far north as Montgomery County, in Maryland, and as far south as Northeastern Alabama. The belt naturally traverses the Piedmont region, and specimens of ore have been taken out of every state it enters. In width it ranges from nine to thirty miles in some instances, yet the quantity of precious metal now obtained from the southern belt is less than the yield of New Mexico alone.

The bulk of the gold which South Carolina produces,—5000 ounces,—comes mainly from one operation. It is one of the oldest mines in the state, and the ore treated is of such a low grade that it does not average more than $4 to the ton. The company operating it has been so successful from the start that it has earned dividends ranging from 6 to over 12 per cent. annually. Apparently the ore supply is inexhaustible, but it is well known that other portions of the south contain ledges which are just as extensive and in some cases nearer the surface. In nearly every case, however, attempts to work them have been failures, owing to the methods employed and not to the fact that the mines were worked out. Had the California discovery not been made, it is possible that this industry would have been developed to very important proportions in the south; but the announcement of the wealth of the Pacific coast, and that which was found later east of the Rocky Mountains, caused the southern field to be neglected.

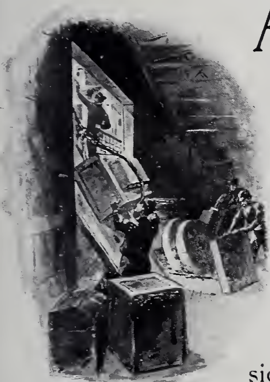
There are lost mines here and there in the west,—deposits of gold which undoubtedly exist, but the locality of which is unknown at the present day. Somewhere in the Mohave Desert is the Bryfogle mine, so called because a prospector of this name came out of the desert with a bag containing several pounds of nuggets. He sold them to secure supplies, and went back, never to be seen again,—apparently the secret of his wealth buried with him. Since then hundreds of fortune-seekers have endeavoured to trace his path, many of them dropping by the way, overcome by hunger and thirst.

As the train on the Southern Pacific Railway passes through Southern California, the passengers can see a group of three hills rising a few miles from the track. On one of these hills is the Pegleg mine, for which search has been made in vain for the last quarter of a century. The first white man who is supposed to have found it was "Pegleg" Smith, who set the people of Lower California wild by the sight of the nuggets which he brought from it; but he also disappeared, and his secret was buried with him. Since then tradition has it that two other white men and one woman have visited the mine, but all are dead, and, so far as is known, they never disclosed the secret of its location. Undoubtedly the southwestern Indians have been familiar with many of the richest deposits, especially the Apaches, and could account for the disappearance of many a prospector who has sought them and never returned to civilisation.

PACKING MACHINERY FOR EXPORT

By Paul Roux

In view of the many complaints which have been made of careless packing of machinery shipped to foreign countries, the suggestions offered by Mr. Roux in the following article are worth noting. The complaints have been directed more particularly against American exporters, and Mr. Roux had in mind the American shipper with special reference to French purchasers when he prepared these remarks for the American Chamber of Commerce of Paris; but they have a general bearing and may not come amiss to others as well.—The Editor.



A MACHINE has much to pass through between the producing factory and its final arrival at the works of the purchaser,—cartage, transportation by rail and by sea, transhipment, loading and unloading, Custom House examination, and perhaps storage for considerable periods in warehouses.

Packing comprises the series of operations which have for object the preservation of the machine in good condition up to the time of final delivery. The care with which these operations are carried out and combined may not only largely affect their own cost, but also the expenses of transportation, custom dues, and storage, and these expenses may amount to a considerable percentage of the selling price.

PREPARATION OF MACHINES

All machine tools after having been completely assembled, inspected, and tested in practical running, should be more or less completely dismounted before packing. It is impossible to lay down fixed rules in this regard, as the extent to which a tool should be dismounted varies with each machine, or rather with each class of machinery. The manufacturer must take into consideration the resistance of the tool and its various parts to rough handling in transportation, and decide as to what extent it should be dismounted to insure safety. It must be remembered that whilst the packing case will protect a machine against blows which it may receive when in a normal position, it offers little protection against side or abnormal thrusts resulting from an overhanging position. Great care must, therefore, be taken to see that no part of a machine is in contact with the sides of the case that is not fully able to withstand the rough handling to which the case can be subjected. The feet of a lathe bed, the base of a shaper, or of a milling machine, may be readily broken by the packing case falling, even lightly, on one of its corners, and without the latter showing any external evidence of the fall.

A most important consideration to be taken into account when dismounting a machine is its volume when packed for shipment. Marine freights are generally reckoned at so much per ton weight, or per 40 cubic feet, at the option of the ship. The exporter has, therefore, every interest to see that the weight, which cannot, of course, be varied, does not occupy a space greater than 40 cubic feet per ton. Nearly all machines, when not dismounted, make up into packages greatly exceeding 40 cubic feet per ton, and even under the best conditions can rarely be packed in cases equivalent in weight and volume. It may, therefore, be laid down, as a general rule, that every effort should be made to reduce the volume as much as possible by dismounting all projecting parts which increase the over-all dimensions of the

packages. On the other hand, the difficulty of assembling parts requiring accurate adjustment must be taken into account, and the exporter must use his best judgment in deciding at what point the difficulties of setting up the machine will outweigh the economy realised by reducing the volume of the package.

This question of reducing the volume is worthy of the closest attention by manufacturers, as the cost of transportation is an important factor in the cost of a machine when delivered at its destination, and the economy realised by paying close attention to the volume of packages may form an appreciable portion of the profits.

The maximum weight of each package must also be carefully considered; freight charges, computed, as has already been shown, according to weight or volume, as may be more profitable to the carriers, are increased very considerably when the weight of individual packages exceeds a certain limit. For instance, the rate for packages exceeding four and one-half tons in weight is double that for packages weighing less than two tons. This increase varies according to the steamship line, but is imposed by all, and must, therefore, always be taken into account.

In addition to its effect on the actual freight charges, the total weight per package when exceeding a maximum of about two tons involves extra charges for loading and unloading. These charges vary according to the equipment of the ports of departure and arrival, and are often very considerable, as when it is necessary to move the vessel under a dock crane, when one is available, or to get up steam on a floating crane to handle the heavy weights.

To sum up, it will generally be advantageous to dismount a machine weighing over two tons, in order to pack it in several packages each weighing less than this maximum. Care must be taken, however, that the total tonnage or volume of the several packages does not exceed that of a single case, and that the difficulties of assembling the machine at its destination do not more than counterbalance the economy realised on transportation charges. It is also profitable to dismount a machine weighing either more or less than two tons when this secures a considerable reduction in volume, and when, as is generally the case with machine tools, the volume exceeds the limit of 40 cubic feet per ton.

DISMOUNTING FRAGILE PARTS

It is generally necessary to dismount fragile projecting parts, even when this will have no influence on the volume or weight of the packages. Whilst it is true that these parts will be properly protected by the packing case during transportation, still they run the risk of being bent or broken during the operations of unpacking and setting up the machine. It is, therefore, preferable to remove them, and to pack them in one or more separate boxes secured in the principal case. All delicate or fragile parts which cannot be removed should be carefully protected against rough handling during unpacking. All screw threads should be carefully covered with wood or rags, and all tapped holes, oil holes, and, in general, all openings through which dirt can reach the interior of the machine, should be carefully closed with wooden plugs.

Manufacturers are especially urged to tag all pieces which may have been removed with labels fully explaining their position on the machine. This precaution may appear exaggerated and useless, if it is considered that the machines will be assembled only by mechanics understanding their construction; but some machines are novelties to many factories, and besides, before arriving at the works of the purchaser they have to pass through the custom house, and sometimes have to be exhibited in a salesroom. Under these conditions it is necessary that people unfamiliar with the type of machine should know exactly the position and function of each of the detached parts.

PRESERVATION

When a machine tool has been properly dismounted and divided up for packing, the very important operations of

protecting the finished parts against rust must be carried out. Lack of care and attention in this operation may have very serious consequences. It is not necessary to point out what serious effects rust may produce on the finished parts of a machine; it should be remembered that after having passed three or four weeks en route, often badly protected from the rain, and always subjected to the effects of dampness, a machine may remain many months in warehouses before being unpacked, and it can be easily imagined in what condition a machine may be found if the finished surfaces have not been protected against rust by a thoroughly efficient coating.

Two things are to be considered in this question of protection,—the nature of the protective coating and the method of applying it. Without stating what the composition of the coating should be, it is urged that this should be sufficiently fluid at the time of application to permit it to reach all parts of the surfaces to be covered, and that it should be entirely free from all trace of acid, in order that it may not attack the metal. It should dry very rapidly, in order that no surface should be exposed accidentally through chafing en route or careless handling in the custom house. It should be readily dissolved with oil, petroleum or turpentine when the machine is ready to be set up at its final destination.

The coating should, of course, be applied carefully to all polished surfaces which can be reached by the atmosphere, and care should be taken that the coating is intact after the machine has been packed, that is to say, when the packing case has been constructed around the machine. It very often happens that the packers carefully coat all polished parts of a machine, but that more or less of the coating is removed during the handling necessary for placing the machine in its packing case, or by contact with the interior braces. The effects of this negligence are generally very serious, because the parts thus exposed are promptly attacked by rust, and the machine cannot be put in perfect condition, even if this be possible, except by long and costly work.

Polished surfaces which are in contact with one another should not be coated; they will be sufficiently protected by the lubricating oil applied for running the machine. Likewise, oil holes should be free from the coating composition, as it is most difficult to completely remove it later on.

Finally, it is recommended that this coating be not applied to any finished parts which, by their position in the machine, are completely protected from all exterior contact, and which are so situated that the removal of the protecting coat would be difficult. For these parts the employment of vaseline or solidified oil is suggested, as this can be readily removed, and, even if not removed, cannot affect the working of the machine. The only precaution to be taken is that the vaseline and oil should be entirely free from acid. As an example, enclosed gearing, such as in the head-stock of a lathe, can be protected in this manner against rust. Vaseline or solidified oil may also be employed for protecting such small detached pieces as may be enclosed in a separate box.

PACKING CASES

The packing case must fulfil two requirements:—it must effectually protect the machine against all shock and injury during transportation, and must facilitate the handling of the machine; that is to say, the packing case is at the same time a covering and a vehicle.

In order to fulfil this double requirement, the case should be specially constructed, and, without fixing general rules, as the details of construction will vary considerably with the forms of different types of machines, the essential requirements will be given for packing cases containing a machine which is of a weight too great for moving by hand.

The bottom is the most important part of the case, considered as a vehicle. If this be well designed, it will not only facilitate handling during transportation and contribute greatly to safety of the machine, but it will be the only part of the case which can be utilised if, after

remaining in show-rooms, the tool is to be shipped by rail to its final destination. The bottom should, therefore, be sufficiently strong to carry the total weight of the machine without the assistance of any other part of the case when balanced on a roller. It should be constructed with two longitudinal battens, in order that the case may be moved on rollers when cranes are not available, and these battens should be bevelled at the ends. Transverse planking, spiked to the battens, forms the bottom of the case. On the bottom, constructed as indicated, two frames should be built around the machine, dividing the length of the case in three parts, in such manner as to support the pressure of ropes or chains when handling with cranes or other hoisting apparatus. These frames will, at the same time, act as supports for the interior braces, and as lateral supports in case the package is laid on its side, which often happens in spite of instructions. Around these principal elements are built the sides, ends, and top of the case, which are designed simply for protecting the machine generally. In constructing the packing case the remarks already made regarding its volume must be borne in mind. This volume is computed from the over-all dimensions, and often a bolt head or a batten badly placed will largely increase the volume.

In designing the packing case it is very necessary to make provision for the examination of the machine in the custom house, and even for removing it completely. It is absolutely necessary, at all events, to arrange an opening in one of the sides or in the cover through which the nature of the machine may readily be seen. This opening should be large enough to permit the examination of all parts of the interior of the case, and to permit the passage of a lantern, if required. It should be closed by a cover secured with screws.

To allow for removing the machine completely from the packing case, in order to determine the net weight of the machine for the custom house, it should be arranged so that the packing and the unpacking may be readily and rapidly accomplished without it being necessary to injure the panels. For this it is necessary that the top and one of the sides be secured with screws instead of nails, and that the position of the interior battens and braces be indicated externally, in order that the screws and nails fixing them may be readily found.

It is especially recommended that the interior of packing cases be not lined with paper. Such a lining prevents the circulation of air, and, if the machine be packed in a damp atmosphere, the humidity, which under other circumstances would have evaporated, will attack the metallic parts wherever exposed ever so slightly. Special attention is called to this point, as practical experience has demonstrated that effects have resulted from lining cases quite unforeseen by the exporter.

LISTS AND DRAWINGS

It is very necessary that the machine should be accompanied by a detailed list of the detached pieces contained in the packing case, which, on unpacking, will show whether any part has been lost during transportation or during the custom house examination. It is most indispensable that this list should be accompanied by a drawing, or cut, showing clearly the machine when assembled and ready for work. This cut should also show all accessories which are indispensable to the machine,—for example, countershafts, keys, and wrenches, change-gears, and so forth. This cut, in lieu of which a drawing should be supplied, will permit the custom house inspectors to convince themselves that the detached pieces actually form part of the machine; otherwise, these pieces may have to pay duties at a higher rate than the machine itself. If the machine has been taken apart and made up into several packages, a cut or drawing should be placed in each case, as, in general, all of the packages are not opened in the custom houses.

These papers, lists, cuts and drawings should be carefully enclosed in waterproof paper and tacked inside the case near the small opening already mentioned, in order that they may be readily accessible. When the dimensions

are such that the papers can be attached to the cover of the opening this should be done.

EXTERIOR MARKS

Once the packing finished, there remains only the proper marking of the cases for identification. All manufacturers know that a case should be marked legibly with identifying marks and numbers, the gross and net weight, the volume, and the name of the port of discharge, the latter in legible lettering at least two inches in height. It is only necessary to call their attention to the necessity of marking the absolutely exact net weight, as even a very small difference between the weight stated and the true weight may cause difficulties in the custom house, and perhaps the imposition of fines. The volume is determined by taking the three dimensions over all. In addition to these marks, indispensable for the transportation of the package, and which should, when possible, be placed on the sides of the case, it is recommended that on each end of the package a short designation of the contents be added. These last named inscriptions are absolutely necessary when the package is to be stored in a warehouse, as they permit of the immediate identification of a case containing a given machine. These inscriptions should not only indicate the type of machine, but should also give its size or number.

Finally, exporters are urged to paint a black circle around the heads of all nails and screws which should be removed in order to unpack the machine with the least work and without injuring the panels and bracings.

If the bottom of the case has been given the special form previously indicated, there is little chance that it will be placed otherwise than upright; it is, however, better to add the usual indications "top," "bottom," and so forth.

If these several suggestions are carefully observed, manufacturers will greatly diminish the risk of injury or deterioration during transport, and will spare the consignee of the machine and the purchaser the trouble, delay and expense which the loss, damage or breakage of an essential part of the machine will cause him. The importance of properly bracing and securing a machine in its packing case has not been insisted upon, as the methods must vary greatly with each type of machine. The manufacturer should know how to so arrange the bracing that the stresses to which the case may be subjected will be properly distributed and brought to bear only on such parts of the machine as may be capable of resisting them.

THE ELEPHANT AS A MACHINE

By M. Barakatullah

THE elephant is a wonderful specimen from the workshop of nature of the skill of the All-wise Creator. It is a sagacious and social animal. In all herds the units are family groups whose several generations are often represented, and when the larger aggregate dissolves, it separates into family groups again. The elephant is a native of Asia, the island of Ceylon and the continent of Africa. It has existed in Kajte-Ban, the Himalayan jungles, and in the lowlands of Vyndhia-Chut Mountains of Central India from time immemorial. Mahabarata, the oldest epic of the world, bears testimony to the existence of the elephant in the land of the Indus thousands of years ago. By the ancient Hindus the elephant was considered an embodiment of wisdom, and hence Ganesha, the Hindu god of wisdom, had an elephant-head, and *Elephas Indicas* was worshipped from Eastern China to the highlands of Central India. The graceful and voluptuous gait of the female elephant has been the theme of the poets and singers of Hindustan in all generations.

The elephant is a curious combination of strength and timidity, fury and docility, and destruction and utility. By nature it is neither vicious nor even of highly irritable temperament, and in its natural state it lives on terms of peace and amity with every animal in the forest. At the rutting season alone the

HAULING HEAVY ELECTRIC MACHINERY FOR THE CAUVERY FALLS POWER HOUSE IN INDIA

ELEPHANTS HAULING A BOILER FOR A CEYLON TEA ESTATE

FROM A PHOTOGRAPH SUPPLIED BY MESSRS. MARSHALL, SONS & CO., LTD., GAINSBOROUGH, ENGLAND, THE MAKERS OF THE BOILER

HOW A STIFF BIT OF JUNGLE HAD TO BE OVERCOME

bull elephant shows some signs of paroxysm called *musti* (madness) in India, which the ancient Persians imagined was due to homesickness, and which speedily passes away. Excepting the "rogue elephants," they are not at all dangerous animals, and the bark of a dog is sufficient to put a herd of wild elephants to flight. When enraged, it assails the rider who annoys it, but does not touch the horse at all. It treats with indifference a spear directed at its head, but shrinks with timidity from the same weapon when pointed at its feet. It will attack the tiger, and pierce a furious bull with its tusks when led to the contest in the arena. Such is this curious creature,—"my lord, the elephant," as it is called in the East,—a combination of contradictions.

The greatest foe of this tower of strength is the tiniest of creatures,—flies of every description can scare the very life out of the huge animal. Man throughout all history has been at the same time the elephant's fast friend and his most formidable foe. He inflicts on the dumb beast a deep wound, and then applies to the sore a soothing salve. For the sake of securing tusks for ivory, the slaughter of elephants was carried to such an extent that it was feared that the species would become altogether extinct. In India and Africa both sexes have tusks, but in Ceylon the female elephant has none.

Elephants are captured in India and Ceylon every year in large numbers in order to be tamed and utilised as beasts of burden. The tusked ones have formed from time immemorial an indispensable part of imperial processions, royal pageants and public ceremonies. The Grand Moguls of Hindustan used to have thousands of elephants of all sizes and of every variety in their imperial studs. In Rapootana the Maharajas often employed elephants in fighting tigers, the bulls and skilled "sant-mars" (trained men with grease rubbed on their bodies) in the arena. In several states of Hindustan there are carriages drawn by elephants on state occasions. Elephants in classic periods formed the most picturesque part of the armies of princes, but in modern times are used for carrying gun-batteries and gun-carriages.

In newly captured elephants conformity and obedience develop rapidly, and hence their training is simple. For three days, or until they will eat freely, which they seldom do in less time, they are allowed to remain perfectly quiet, sometimes with a tame one beside them to give them confidence. Where many are being tamed, each new captive is put between the stalls of half-tamed ones as soon as it takes to food.

This stage being over, tamed ones are put on either side, and the head of the stable stands in front of the wild one holding a long stick with a sharp iron point. Two men are then stationed, one on either side, assisted by tame elephants, and each holding an "ankus" (crook) toward the wild elephant's trunk, whilst one or two other men rub their hands over his back, keeping up all the while a soothing and plaintive chant, interlarded with endearing epithets, such as "Ho, my son," "Ho, my father," or "Ho, my mother," as may be applicable to age and sex.

Then the wild elephant is taken to the tank to bathe in company with tame ones with a particular detail of process. Gradually, after a few weeks, the aid of a decoy is dispensed with, and the animal is taken alone to the tank, with its legs hobbled with a rope and men pointing crooks at its head and ears. Thus, some become tame in a few months, and others take longer,—for the process of taming is dependent upon the disposition of each individual elephant.

The first employment of a newly-tamed elephant is in treading clay in a brick field, or in drawing a waggon in double harness with a tame companion. But the work in which the display of sagacity renders the labour of the elephant of the highest value is that which involves the moving of heavy material. Hence in dragging or piling timber, or in transporting stones for the construction of walls and the approaches to bridges, the services of the elephant in an unopened country are of the utmost importance. When roads are to be con-

structed along the face of steep declivities and the space is so contracted that risk is incurred, either of the working elephant falling over the precipice or of rocks slipping down from above, not only are the measures to which the sagacious animal resorts the most judicious and reasonable that could be devised, but if urged by its keeper to adopt any other, it manifests a reluctance sufficient to show that it has balanced in its mind the comparative advantages of each.

An elephant appears on all occasions to comprehend the purpose and object that it is expected to promote, and hence the animal voluntarily executes a variety of details without any guidance whatever from its keeper. Herein lies the superiority of the elephant over the horse. In moving timber and masses of rock its trunk is the instrument on which the elephant mainly relies, but those who have tusks turn them to good account. To get a weighty stone out of a hollow, the elephant will kneel down so as to apply its head to move the stone upward; then, steadying the stone with one foot till it can raise itself, it will apply a fold of its trunk to shift the stone in place and fit it accurately in position. This done, the elephant will step around to view the stone on either side and adjust it with due precision. The animal appears to gauge its own task with its eye, and to form a judgment as to whether the weight is proportioned to its strength. If doubtful of its power, it hesitates, and if urged against its will, it roars and shows temper.

In clearing an opening through forest land the services of elephants are great, but in dragging and piling felled timber they are greater still, for in the latter work the animal shows an intelligence and dexterity which is truly surprising, and does better work than even dock labourers. Jungles and brushwood may be thrown down by the mere movement of elephants through them. It takes to its "mahawat" (keeper) and becomes attached to him. One of the reasons of its sociability to man is that it is fed on the best food made of huge loaves or discs of bread, with "ghee" (clarified butter), sugar, almonds, etc. The great mogul emperors used to bestow honours upon the feudal lords by giving them so many elephants, with as many villages to keep the animals. Hence the Persian poet, Hafiz, says:—"Either you should not make friends with the lords of elephants, or else you should build a house to accommodate those royally expensive beasts."

THE TELEPHONE IN THE UNITED STATES

By Herbert Laws Webb

THE United States is the home of the telephone, and certainly the telephone has prospered luxuriantly in the country of its origin. There are many characteristics which distinguish an American from an English city, some of them pleasing, others not; but none is so striking to the observer interested in modern methods as the extraordinarily general use of the telephone. You see telephones literally everywhere. On the office desk the telephone instrument is as regular a part of the equipment as the inkstand. In your hotel you find a telephone in your room, from which you can talk not only all over the city, but all over the country. In the street you are never out of sight of a sign informing you that there is a public telephone within. In your friends' houses the telephone is available upstairs and downstairs, it finds a place in my lady's boudoir as well as in the hall or library.

Every good-class shop has the telephone service, and most of the larger establishments have elaborate exchange installations with a telephone in every department, so that customers can talk directly to the particular branch with which they have business. The convenient public telephone station is to be found wherever a public telephone is likely to be wanted,—in the principal railway stations, in hotels, restaurants and theatre lobbies, in all the large shops,—or "department stores," as they are called,—and in very many small ones much used by the general public, such as tobacconists and chemists; in fact, except in a church, one is never out of sight of the ubiquitous telephone in an American city. The casual or general public use of the telephone is catered to so completely that in many restaurants connecting points are provided at different parts of the room to which a portable telephone set may be joined in a moment, enabling customers to telephone messages between courses.

Comparisons have a bad name, and figures have no particular meaning to many people. One comparison drawn during a recent tour through part of the United States, devoted principally to a study of the telephonic conditions, made a strong impression as illustrating very forcibly the great difference in the development of the telephone in Great Britain and in America. In Great Britain there were in service at the end of 1903, in round figures, some 300,000 telephones. In America the first four cities visited had telephones in service as follows:—

New York and suburbs	130,900
Brooklyn	65,000
Boston	54,000
Chicago	76,000
Total	325,006

Here we have four cities, with an aggregate population less than that of Greater London, using a somewhat greater number of telephones than the whole of Great Britain and Ireland.

An array of statistics might be produced to illustrate the enormous development attained in telephone work in the United States, and still the illustration would be less striking, perhaps, than that afforded by the contrast just

cited. What is even more remarkable than the pitch of progress already reached is that there is in sight no apparent slackening in the rate of development.

The American Telephone & Telegraph Company and the companies allied with it, which operate in the various states all over the Union, have invested new capital in the upbuilding of the telephone system at the rate of about forty million dollars a year for several years past, and the capital expenditure on new works is expected to reach the imposing sum of nearly fifty millions of dollars during the current year. That means that the American companies are spending on increased facilities during a single year nearly as much as the whole amount of capital invested in the telephone system of Great Britain. As the president of the American Telephone Company said in a recent annual report, the demand for telephonic facilities in all parts of the United States is greater than the supply.

There are several reasons for this prodigious development of the telephone service in the United States,—a development which promises to make the use of the telephone in that favored country practically universal within a very few years,—but foremost among them all is the fact that there is no government monopoly in telegraphs in America. The telephone there has consequently escaped the blight of official interference which has restricted its development in every European country. In the United States, the Federal Government has wisely left the conduct of telegraph and telephone communication to private enterprise, and the results have amply justified its policy of non-interference. There has been absolute free trade in telephony, and the telephone companies have been enabled to build up their business on the broad lines of supplying a public demand in the most efficacious manner. They operate under the general telegraph law, which regulates the building of telegraph lines along the public highways, and under their individual charters granted by the states in which they are incorporated; they are subject to the codes of regulations affecting the construction of electric wires adopted by the various municipalities, and, in some cases, to special telephone "franchises," or charters, granted by the municipalities, and they are subject to state and local taxation. But otherwise they are entirely free from government interference and regulations; the life of the business is unlimited, and all questions relating to the rates, the service and the running of wires lie between the companies and the public. The rapid and effective development described above,—a development attained nowhere in Europe under the régime of government control,—is proof positive that these questions give rise to little friction.

The quality of the telephone service in American cities, as a general rule, is excellent. The answer to a call is quick, and the work of completing the desired connection is rapidly and accurately performed. In the larger cities the wires are almost entirely underground; in fact, in New York the greater proportion of the distributing wires are carried directly underground into the subscribers' premises; from this method of construction there results a system that is proof against interruption due to extremes of weather. Even a great conflagration can cause only a local interruption in the particular area affected by the fire. Consequently, a service is produced which, besides being extremely prompt, can be depended upon to be always in working order. When a telephone service of this character is so largely developed that it is used by a very considerable proportion of the community, —in New York there is, roughly speaking, one telephone to every five adult inhabitants,—it can readily be imagined how enormously valuable a piece of the machinery of life it becomes, how great a factor in both business and social affairs.

So far for the results. While a description of the means by which these results are achieved must necessarily deal somewhat with the technicalities of the telephone business, yet even the non-technical reader can hardly fail to

be interested by some account of the machinery of a modern city telephone system and of the business methods by which that system is made available to such an enormous number of users. The American telephone companies have pursued a policy which is distinguished by two main features; first, to bring the service to as high a pitch of perfection as possible, and second, by means of educating the public in the use of the service and by making rates calculated to appeal to all classes of the community, to create a demand for the service so widespread as to be practically universal.

In pursuance of the technical branch of this policy there has been evolved, after nearly two decades of invention and experiment, a method of working the telephone service which is largely automatic. The calling signal is displayed at the exchange by the simple action of lifting the telephone from the hook at the subscriber's station; there is no crank to turn or button to press. Conversely, the replacement of the telephone on its rest at the end of the conversation automatically displays at the exchange the signal to disconnect. Thus, the operation of the service from the subscriber's end of the system is reduced to the simplest possible terms, the necessary acts of taking the telephone from its rest for use and of returning it to its proper place after use, automatically giving the signals to the exchange, which in the older systems of working required the manipulation of buttons or cranks and more or less demand on the memory of subscribers.

This modern system of telephone exchange working is known as the "common battery" system, the underlying principle of the method being that all power,—for operating the various signals at the exchanges as well as for energising the telephone transmitters at the subscribers' stations,—is supplied from a common source, a battery of storage cells situated at the exchange. The adoption of a central supply of current does away with batteries and hand dynamos at the subscribers' stations, and, therefore, materially simplifies the apparatus required in each telephone set, resulting in a corresponding simplification of the work of maintaining those sets. But when the working of the common battery system is followed through the exchanges it is seen that from the main feature of this highly ingenious system,—the centralisation of the supply of power at the exchange,—there flow many advantages in the working of the service.

The subscribers' signals for calling and disconnection are, as we have said, given automatically by the necessary acts of taking down and replacing the telephone. At the exchange these signals are conveyed by means of miniature incandescent lamps. This form of signal has several advantages over the indicator shutter formerly used; it is more compact, it is silent, and it furnishes a signal that is more assertive than an electro-mechanical device. The lamp signal, by reason of its compactness, can be associated immediately with the switch to which it corresponds, which was not possible with the electro-mechanical indicator. This increases the accuracy and speed of the operating.

The earlier forms of electro-mechanical indicators were restored to their normal position by hand, an operation, many times repeated during the day, involving much labour to the operators. Later, an indicator was invented which was automatically reset when the operator inserted her plug in answer to a call; but this device had the disadvantage of occupying more space in the switchboard than the manually restored indicator. The lamp signal solves both the space and the labour difficulty, as it occupies an extremely small space,—the telephone lamp is about three-eighths of an inch in diameter,—and is automatically extinguished when the operator inserts her plug in answer to a call.

As most telephone users know, connection between two subscribers' lines is made at the exchange by means of a pair of flexible conductors terminating in plugs which engage with the switches to which the lines are connected in the switchboard. One of the great difficulties in operating a telephone exchange is the proper supervision of connections

which are established, the supervision in this case being aimed at preventing two lines being left connected a moment longer than is necessary. In all the older methods of working it is necessary for the subscriber to perform some definite act,—other than the replacement of the telephone on its rest,—in order to give the exchange the signal to disconnect; a crank has to be turned or a button to be pressed, or even a button pressed and an order spoken to the exchange. Many subscribers forget to turn the crank or press the button, and the operators consequently have to watch the cords in order to insure that the lines shall not remain connected (and, therefore, "engaged") longer than is necessary.

In the common battery system the supervision is automatic. Associated with each of the cords by which the connection is established is a lamp signal, set in the shelf by which the cords and plugs are supported; as long as the two lines connected are in use these lamps remain inert, but when the two telephones are replaced by the subscribers the two lamps glow, and the operator, thus positively assured that the conversation is finished, extracts the two plugs from the switchboard, so both freeing the two lines connected and automatically extinguishing the two "supervisory" lamps. If at any time only one lamp glows, the operator knows that the subscriber corresponding to the other lamp is "holding the line," and she does not interfere; the lighting of the two lamps together is the signal for disconnection.

It will be seen that by this ingenious device the operator is constantly and positively informed of the state of affairs on any two lines that she has connected; she has not to "listen in" or to enquire to guard against the mistakes or forgetfulness of the subscriber. She is governed solely by the lamps, and the subscriber gives the disconnection signal by the simple act of replacing his telephone; there is no tax on his attention or memory for the performance of any special act to signify that he has finished talking. As may readily be imagined, this automatic method of working adds largely to the speed and accuracy of the service, the work is simplified both for the operator and for the subscriber, and the required signals are given not only positively, but instantaneously.

A little thought on the question of dealing with the traffic of a telephone exchange shows that the prompt disconnection of lines after a conversation is finished is of great importance to the subscribers. The majority of telephone users would agree that the most annoying feature of the use of the telephone service in a large city is the frequency with which the report "engaged" is received in answer to a call. "Engaged" means that the operator has applied an electrical test to the line demanded and received a signal, a characteristic click in her head telephone, which assures her that the line wanted is connected to another. When the signal for disconnection at the end of the conversation is dependent on the memory of the subscriber, it is the invariable experience of telephone operators that many subscribers habitually fail to give that signal. Consequently, on many occasions two lines remain connected for an appreciable time after the precise moment when the connection is no longer required, and as long as they remain connected both of them test "engaged" to every operator who may approach them with a call from another subscriber.

In New York it has been found that whereas under the old method of relying on the subscriber to give the disconnection signal, and on the supervision of the operators to discover when the signal had not been given, there was an average interval of over seventeen seconds between the end of a conversation and the moment when the two lines were disconnected and restored to their normal condition, this interval has been reduced to less than three seconds since the introduction of the common battery system. In telephone work every transaction is measured in seconds; during the busy hours of the day calls rain into a telephone exchange in a perfect torrent, and a gain of fifteen seconds in

each transaction is a most important one and cannot but have an appreciable effect in reducing the aggravating "engaged" report.

Although the improved common battery system has been adopted in England by the National Telephone Company and by the Post Office for all their new work, where the large American cities have the advantage is that in practically all of them the improved service is given throughout. The whole system is uniform. In fact, it may be said, broadly speaking, that the method of working the telephone service all over the United States is now uniform, all of the principal cities and many of the smaller ones having changed over to the new system within the past five years. This has involved a prodigious amount of capital expenditure, as it has meant in all cases new subscribers' instruments and new exchange apparatus. But, as is well known, American business men do not shrink from heavy capital expenditure if the result is to be improvement in working and economy in operating expenses.

The rapid march of invention in telephonic working is well illustrated by the history of the New York system. Up to 1888 the New York exchange was operated by means of overhead wires, and single, or earthed, circuits. A law was passed about that time forbidding the use of overhead wires, and underground conduits had to be built and metallic circuits adopted, as single-wire circuits will not work in underground cables. This involved the reconstruction of all the exchange switchboards. The work of replacing the condemned pole lines by underground cables and of bringing the new exchanges into use occupied two or three years.

Then, early in the nineties, an improved form of switchboard was invented, which was promptly adopted, and several of the principal exchanges were rebuilt with the improved system. Some of the switchboards discarded had been in use only four or five years. In 1898 the common battery system was sufficiently developed to be put into practical service, and late in that year it was adopted in one of the New York exchanges. This method of working was found to possess so many advantages that it was decided to convert the entire New York system, which then consisted of thirteen exchanges and some 30,000 subscribers' stations. This work not only involved the replacing of all the subscribers' instruments by new ones of a different style and the equipment of all the exchanges with new machinery and switchboards, but also the construction of a number of new buildings, and extensive changes in the cable plant.

The whole work of rebuilding was completed before the end of 1901, the period of transition being marked by a notable development in the system; from about 30,000 stations in 1898 the number grew to nearly 70,000 at the end of 1901. At the present time in the boroughs of Manhattan and the Bronx, which constitute what is generally known as New York City, over 130,000 telephones are in service.

Similar changes in the mechanical and electrical constitution of the telephone service have taken place in most of the other cities in the United States during the past few years. In some, for special local reasons, the work of reconstruction has been delayed and is still in progress; but in most places the whole system is converted, and the latest method of working is in general and uniform use almost all over the country. The American, wherever he goes, finds a uniform style of telephone and a uniform method of operating the service. The precise degree of efficiency of the service in point of speed may vary in different places, as this is to some extent dependent on the personal equation both of the management and of the subscribers, but everywhere it is high.

It is clear that the technical policy of the American telephone companies has been to furnish the best service that could be produced, adopting, to that end, every improvement that invention has devised, and this policy has been carried out so thoroughly that it has entailed in some cases, as we have seen, the entire rebuilding of a large city tele-

phone system twice within a decade. While the enormous development that has been attained in the telephone service in the American cities, coupled with the high standard of efficiency maintained, make that service of inestimable value to the community, it must not be imagined that an enterprising technical policy alone has accomplished the phenomenal results achieved.

The telephone companies have not simply provided the machine and sat down and waited for the public to come to them and ask to be allowed to use it. On the contrary, they have pursued also a most "forward" business policy. They have gone out on the highways and byways and said to the public, "Here is a most valuable service, the most useful service of modern times. You should not be without it, for a hundred reasons, and we will supply it to you at a price which you can afford to pay."

In the American papers you will read advertisements headed, "Don't Travel, —Telephone!" "The Telephone is the Quickest Messenger." "Telephone Service at your House or Office for —— a month," and so on. The telephone service and its manifold advantages are advertised freely, and the rates are based on a sliding scale, so that the user pays for what he uses.

In the early days of the telephone industry the American telephone companies adopted the system of charging for service, which is still in force, generally speaking, in Europe, *i. e.*, what is known as the "flat" rate,—a fixed annual charge per line for unlimited use of the service. In a few instances a departure from this inflexible method was made and a tariff introduced which was based on the amount of use made of the service by the subscriber, thus enabling the small customer to obtain service at a moderate rate and causing the large user to pay in proportion to his use.

But it was not until about ten years ago that the "message rate" tariff began to be widely adopted and scientifically worked out to meet the needs both of the telephone service and of the public. The proper working of the "message rate" tariff demands that there shall be no maximum rate,—that each and every telephone message shall be paid for, just as every letter sent through the post must bear its corresponding stamp. If the flat rate is kept in force, the result is that all the large users take the flat rate and only the very small users the message rate. This causes many inconveniences, both of a financial and of a technical nature. The small users, originating little traffic, pay a very small rate, while the large users, having unlimited service, do not pay in proportion to the work they cause, and, by overloading their lines, block the way to incoming calls, so causing other subscribers to receive a bad service.

In some American cities the flat rate has been retained, and the telephone user has the option of paying a fixed annual sum for unlimited service or of paying according to a graduated scale, varying with the number of messages he sends in a year. In New York, however, the flat rate has been entirely abandoned, and a comprehensive tariff of message rates has been worked out which meets the wants of all classes of the public, from the modest resident or shopkeeper up to the large business establishment, whose telephone service can only be adequately handled by a satellite group of lines and stations known as a "private branch exchange."

The flat rate in New York was originally $150 (say £30) a year. When the system was changed from overhead single wire to metallic circuit underground, the rate was raised from $150 to $240 a year for the metallic circuit service, the justification for this increase being the greatly increased cost of building and operating the system. This rate was considered high, and the development of the system was extremely slow during the time it remained in force. To English ears such a rate sounds extremely high, $240 being the equivalent of over £49. But it must be borne in mind in considering all American charges that the purchasing power of money, generally speaking, is considerably lower than it is in Great Britain. Therefore, in comparing American

telephone rates with those current in Great Britain, due regard should be given to the difference in conditions between the two countries.

The effect that the message rate tariff has had upon the development of the telephone in New York is strikingly illustrated by contrasting the period during which only flat rates were in vogue with the period during which the message rates have entirely supplanted the flat rate. In 1894 the New York system, after nearly sixteen years' existence, had about 10,000 stations. In the summer of that year the first message rate tariff was tentatively adopted and an active policy of advertising the service and canvassing for subscribers was begun. In a very few years the system was doubled in size, as in 1897 there were over 25,000 stations where in 1894 there had been only 10,000. As experience was gained in the working of the message rates, the tariff was modified in various ways until, as has been said, a thoroughly comprehensive scheme of rates has been evolved which seems to meet all requirements.

During the past few years the annual increase in subscribers has reached prodigious figures,—between 25,000 and 30,000 each year,—and the total increase in telephones in New York in nine and a half years has been 120,000. So that in less than ten years under message rates twelve times as many telephones have been put in service as were established during sixteen years under the flat rate régime.

The basis of the New York tariff is a minimum annual charge for a certain number of messages, the rate for additional messages being on a sliding scale, so that the price per message decreases as the number of messages used in a year increases. The minimum rate for an individual line, for business purposes, with 600 messages to be sent in a year, is $75 (say £15.10). Additional messages are charged at 8 cents (4d.) each at first, and gradually decrease as the subscriber uses a larger number to 5 cents (2½d.) each. But if the subscriber estimates his annual use in advance and contracts for additional messages by the hundred, he gets them at a lower rate, beginning at 6 cents (3d.) each and running down to 3 cents (1½d.) each.

Should the subscriber not use up all the messages he has contracted for, the company returns or credits, at the end of the contract year, whatever amount has not been earned. The tariff for an individual business line runs up to 4500 messages in a year for $228 (£47), that number of messages, corresponding to an average of fifteen per working day, being considered the maximum outward use which should be made of one line, having due regard to the availability of the line for inward calls and to the great concentration of telephone traffic at certain hours of the day.

Provision is made for the busy establishment requiring a large use of the telephone service, first by a rate of $48 (£8.12) a year for an auxiliary line, affording a double-track system, so to speak; and second, by a "private branch exchange" tariff, which sets forth the rates for lines and stations to be used in groups by those establishments whose telephone traffic is too voluminous to be effectively handled over one or two lines. This branch exchange service has proved in New York and in other American cities to be the most effective cure for the "engaged" trouble. It is universal experience that the subscribers chiefly responsible for "engaged" are those who make very large use of their lines for outward calls, thus blocking the way to the calls which others are trying to make to them.

The obvious remedy is for the very busy subscribers to take more telephonic facilities; but as the blocked inward calls go unperceived by them, it is difficult to persuade them to do so. The private branch exchange system, which was devised to cope with this evil, consists, as its name implies, of a small telephone exchange system installed on the premises of the subscriber and connected by two or more junction lines to the nearest exchange of the general system. From the branch switchboard, which is served by a trained operator, lines are

extended to the various departments in the office or building.

The advantages of this method of supplying the telephone service to a busy concern are many. By means of the extension telephones the service is made available exactly at the points where it is wanted, those who have to use the service much do not have to go to the telephone,—it is within reach of the right hand. The operator at the switchboard receives all the incoming calls and directs each one to the telephone of the particular person wanted, acting as a distributor of the inward traffic. She also gets from the extension instruments the orders for all outward calls and works them through the exchange.

With the private branch exchange the telephone traffic of a busy establishment is handled by an expert, well versed in the importance of accuracy and promptness, instead of by an office boy who too often considers accuracy and promptness of no importance whatever. The provision of several lines between the branch switchboard and the main exchange ensures there being sufficient channels of communication to enable the incoming traffic to have a clear way, and so the branch exchange service helps to lessen the "engaged" trouble and enhances the value of the service to the subscriber. A great advantage of this class of service is that the arrangement is extremely flexible; as the subscriber's business grows, more lines and more extension stations can be added and the telephonic facilities thus kept equal to the demands of the telephone traffic. Conversely, of course, should the subscriber's business fall off, the number of lines and stations could be reduced to fit the altered circumstances.

This private branch exchange service has enormously aided the development of the telephone in American cities. It enables the large business houses to get the utmost value out of their telephone service, and in such establishments as hotels and flat buildings it permits of the supply of the service to all guests and tenants at very moderate cost. There are now between three and four thousand branch telephone exchanges in New York, and the number of expert telephone operators in private employ is actually greater than those on the regular operating staff of the telephone company. The number of stations in these branch exchanges runs all the way from five or six up to several hundreds.

At the Waldorf-Astoria Hotel there was recently completed an installation comprising no fewer than 1200 telephones; there is a telephone in every room of the hotel and in all the working departments, giving service locally in the hotel, in the city, and anywhere in the United States reached by the vast system of long-distance lines. This is probably by far the largest installation of telephones under one roof in the world. In all the large cities in the United States it is the exception to find a leading hotel where the telephone service is not supplied in this way to every room, and the convenience of this arrangement is something that must be experienced to be fully appreciated, especially as in the American city there is hardly anything you want done or arranged for that cannot be done or arranged for by telephone.

In hotels, too, the branch telephone exchange is of great aid in the service of the hotel proper. If you want anything,—and in hotels you are expected to want all sorts of things,—you do not have to ring for a servant and then give your order; you telephone your order to the office, and it is put in hand with the minimum of delay; thus, you save time and the hotel saves labour. This internal use of the private branch system is valuable in large business establishments as well as in hotels.

The usual method of charging for the private branch exchange service consists of a certain rate for each line and for each station and a wholesale rate for the messages. Thus, in New York the tariff is $36 (£7.4) for each line between the main and the branch exchange and $12 (£2.8) for each extension station, while all messages are charged for at the uniform rate of $3 per hundred,—equivalent to 1½d. each. There is also an annual charge for the rental of the branch switchboard, which varies with the size

of the switchboard required. In all cases a "message" means an effective call, and all messages are charged to the subscribers who originate them, so that the incoming calls are naturally free to the receiving subscriber.

In hotels, where the management bears all the charges of the upkeep of the installation, the calls are charged to guests at the regular public station rate, which, in most American cities is, for a local call, 10 cents (5d.). As the hotel management buys calls from the telephone company at wholesale rates, the profit on the telephoning done by the guests is generally in excess of the cost to the hotel of the service as a whole. In this way the hotel not only offers a valuable facility to its guests, but it gets a very useful by-product in the interior service and makes a profit into the bargain. The guests of an American hotel use the telephone service very freely. During the first month of working of the Waldorf-Astoria Hotel installation in New York the business amounted to over 30,000 calls, exclusive of calls local to the hotel; these latter, being free of all charge, are not recorded.

From the foregoing sketch of the rates and classes of service elaborated by the American telephone companies, it is seen that rates and classes of service have been devised to suit almost every possible user. The great merit of the message rate tariff is its extreme flexibility. When it is applied in a thoroughly logical manner, with no flat rate for the large user to take refuge under, it facilitates not only a very wide development of the telephone, but also a thoroughly satisfactory service. The abolition of the flat-rate unlimited line makes it impossible for the large user to block his lines always to inward traffic and to monopolise the junction lines between exchanges, so spoiling the service for other subscribers.

The reciprocal nature of the telephone service is one of its peculiar features that is little appreciated by many telephone users; but since in every telephone connection there are two subscribers concerned, it stands to reason that, unless both use the service in the most effective way, there will result more or less inconvenience at least to one of the two, and generally to both. The average user of the telephone service is apt to regard it from the point of view of his own convenience only; to consider, perhaps not unnaturally, only his own calls; and to ignore the fact that he is part of a system and that the other users depend partly upon him for the quality of service that they receive.

One of the very interesting features of the telephone industry in America is the systematic education of the public in the peculiarities of the telephone service which has been undertaken by the American telephone companies. Reference has already been made to the manner in which the advantages of the service and the rates at which it is supplied are advertised in the daily papers. This newspaper advertising is supplemented by attractively printed and illustrated circulars and booklets which are issued at frequent intervals and distributed wherever it is thought interest in the telephone service can be aroused. In these publications not only are the advantages of the service and its application to all kinds of business and social requirements expounded, but pointed information is given as to the proper use of the service, the effect that one subscriber's use of it has on that of another, the suitability of certain classes of service to certain situations, and so forth.

This propaganda is directed and followed up by a special department of the company whose mission it is to expand and solidify the company's business relations with the public. Thus, a systematic campaign is carried on, first to convince the public of the extreme usefulness of the telephone service and to make widely known the rates at which the service is supplied; next, to induce as many of the public as possible to take the service; then to educate the actual users in the proper use of the service; and finally to persuade the large users to employ the telephonic facilities best suited to give both them and their correspondents the best possible service.

It would be astonishing if exploitation so highly organised and energetically

conducted as this did not yield substantial results. The results have been, as already shown, to secure a development of the telephone service which is unapproached in any European country,—a development which is being conducted on the soundest lines and shows no signs of abatement.

Perhaps the most striking feature observed during a recent inspection of the telephone conditions in a dozen of the large American cities was the very practical demonstration of confidence in the almost unlimited future expansion of the telephone system. In almost every city large telephone buildings to accommodate substantial additions to the telephone plant were in various stages of construction, and new exchanges, planned on the most generous scale, were either just completed or just about to be. During recent years the annual increase of subscribers in the large cities has been reckoned in thousands, and in the very largest, such as New York, Chicago, Philadelphia, and Boston, by the tens of thousands. There is evidently perfect faith that this phenomenal development will be maintained for a long time to come, and that faith is backed in all directions by works of a most substantial description.

The rates charged for telephone service in American cities sound high to British ears, though, as has been said, they must be considered in connection with the local value of money and with the local conditions. It may be said, in passing, that while the wide development of the service proves that Americans generally do not regard the rates as exorbitant, still they are sufficiently high to tempt capital into competition. Competing companies have established telephone systems in various cities, and especially in the smaller towns in the West; but, so far, the original companies seem to maintain their position in the public favour in all the large cities, having much larger systems than the opposition companies.

The logical deduction from the experience of the American telephone companies, however, seems to be that to attain a sound and wide development of the telephone service depends not so much on extremely low rates as on the supply of a thoroughly reliable and efficient service, and on the education of the public in the usefulness and peculiarities of the service. Perhaps a fairer statement would be that while a first-class service is the prime requisite and systematic education of the public the second, these must be accompanied by a scheme of rates that will be accepted by the public as fair and reasonable and will appeal to the largest possible proportion of the public. The elastic tariff which results from the basing of the rates on the message instead of on the rental of the line and station seems to be the one system of telephone rates which meets these requirements.

INDUSTRIAL LOCOMOTIVES

FOR MINING, FACTORY, AND ALLIED USES

Part I.—Steam Locomotives

By J. F. Gairns

THE design and use of locomotives for mining, factory and analogous work is not a novel subject for treatment in technical magazines and journals. Much valuable information has been published concerning locomotives built specially for such "industrial" use as distinct from work on standard railways for conveying booked passengers and paid-for goods on a more or less large scale and under circumstances where speed and economical working are important considerations. But the subject is a very wide one, and the descriptions of these specially designed locomotives are scattered, and are mostly dealt with in sections only, so that, in view of the already extensive, and rapidly extending, adoption of the locomotive in place of animal and manual power in and about works, factories, mines, quarries, etc., and generally as an "industrial" agent, it is thought that a review of what has been and is being done by locomotive-building firms, prepared in a comparatively thorough, though by no means exhaustive, manner, will be appreciated by the readers of this magazine, and may be useful to prospective users of such specially designed locomotives.

It is difficult to decide where ordinary design leaves off and special design to meet special circumstances commences; but while a few locomotives, such as are best described as contractor's locomotives, will be included, this article will deal only with mining (for use both in and about mines) and factory locomotives for use under conditions which call for radical departures from orthodox or ordinary designs, other than mere dimensional differences. On standard railways steam is almost universal as a motive power, electricity being its only rival worth mentioning, though compressed air and internal-combustion engines have had limited trial; but for such work as this article is concerned with, the three principal sources of motive power, steam, compressed air, and electricity, are more equally matched, and while each is particularly suitable for certain uses, the rivalry, in a general way, is keen. The explosion motor, too, is now entering the arena as a contestant.

Speaking broadly, it may be said that the considerations which govern the choice of motive power, other than such matters as the availability of electric generating and air compressing stations, or the possibility of using natural forces, waterfalls, etc., for central station purposes, are substantially as follows:—

1.—Dimensional limitations.

2.—Objections to the use of motors in which a furnace is comprised.

3.—Whether locomotive power is to be employed in single units or on a more or less extensive and systematic scale.

4.—The loads to be hauled, the distance to be covered, curves, the gradients to be surmounted, and the character of the permanent way.

5.—Whether the locomotives can be manipulated by experienced men or by ordinary and comparatively unskilled labour.

6.—Possibility or probability of a particular motive power when used under certain conditions, though not of itself dangerous, being a source of danger to

FIG. 1.—FOUR-WHEELED SADDLE TANK LOCOMOTIVE BUILT BY MESSRS. PECKETT & SONS, BRISTOL, ENGLAND

men employed near, or in connection with, the locomotive.

All or most of these considerations may be important in some cases; in others, factories such as have been above excepted act to influence matters, while in some instances the choice of a particular motive power results from selection by engineers on the score of convenience or economy. The firms who make a specialty of these "industrial" locomotives are well aware of the oftentimes exacting conditions which have to be taken into account; and, as will be seen hereafter, much ingenuity has been displayed in the design of locomotives to meet greatly varying circumstances, while it is rare that, however complicated and difficult the position may be, they cannot design a locomotive that will be applicable and suitable, and so some other motive system has to be employed.

Considering now the governing conditions set forth above, the first, that of "dimensional limitations," calls for the design of locomotives of restricted width and height, and sometimes of length and weight as well, though these latter operate more in connection with local conditions, such as curves and the character of the permanent way. As the diminution in power allowable is rarely proportionate to the required lessening of dimensions, it follows that the design of these "restricted" locomotives calls for much skill on the part of the designers, and great interest attaches to their work. In some cases, the boiler and other parts have to be pitched very low and to be specially constructed, while the driver often travels in a sitting position, and even in a lying-down position. In other instances, the projecting parts, chimney, cab, etc., are arranged so as to be collapsible when required. Indeed, it is hard to express briefly the many ingenious and interesting devices which have to be employed to comply with conditions, so that the examples to be described must speak for themselves.

Owing to the nature and circumstances of the work to be done it is often imperative that no locomotive in which a furnace is comprised shall be employed, as for instance, in "fiery" and many "non-fiery" mines, and in connection with factories concerned with explosive and inflammable materials. Sometimes electricity is not admissible as a motive power because of a possibility of sparking or fusing of safety devices under dangerous conditions.

If only a single locomotive is to be

used, an independent type must be employed, such as a steam or "petrol" engine, unless there is already electric or pneumatic power available from a plant provided for other purposes. If locomotive power is used on a larger scale, a central electric generating or air compressing plant can be advantageously installed, and, therefore, non-independent locomotives can be used.

Conditions 4 and 5 are self-explanatory, and, therefore, require no special mention here. Condition 6 covers such considerations as the emission of smoke and fumes in confined spaces, liability to breakdowns, danger from exposed electric conductors, etc.

The subject being thus generally introduced, representative examples of the locomotive designer's art will be described and illustrated with photographic reproductions and drawings kindly supplied for this article by the various firms concerned. In the first section are included steam locomotives working according to ordinary methods and also designed on special systems; in the second section, to appear in the July number of this magazine, compressed air and internal-combustion locomotives will be dealt with; and in the third section, to appear in the August number, electric locomotives will receive attention.

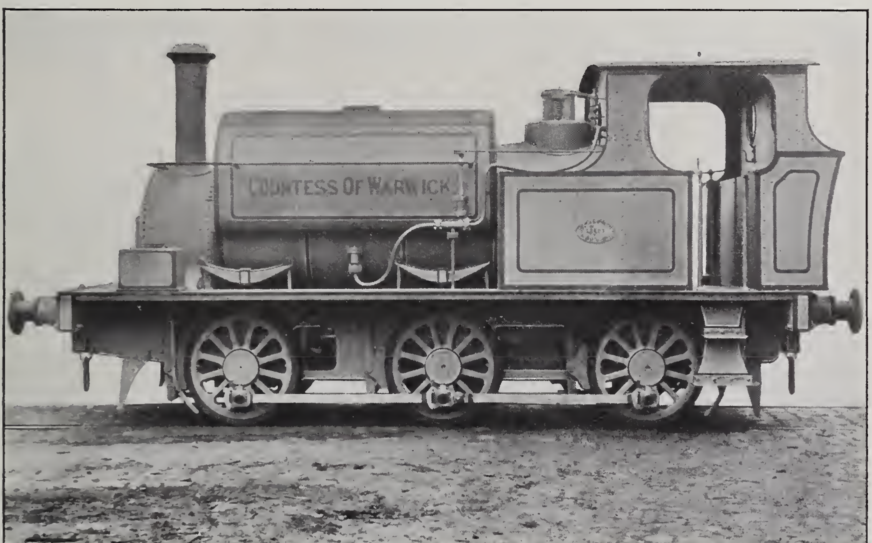


FIG. 2.—A SIX WHEELED SADDLE TANK LOCOMOTIVE BUILT BY MESSRS. HUDSWELL, CLARKE & CO., LTD., LEEDS, ENGLAND

I.—STEAM LOCOMOTIVES

As an introduction to the study of steam locomotives for industrial use it will be fitting, for the sake of completeness, to briefly describe a few specimen engines as provided for contractors' use, which do not, however, possess any very noteworthy features as regards special design. For this purpose several photographs are reproduced, selected from a considerable number in the writer's possession. It will, of course, be understood that most builders of contractors' locomotives have a complete series of designs suited for varying requirements, of which the locomotives selected for illustration indicate the general characteristics, apart from the differences in practice of each firm.

Fig. 1 illustrates a fairly powerful and handy four-wheeled locomotive built by

FIG. 3.—A SIX-WHEELED SADDLE TANK LOCOMOTIVE BUILT BY MESSRS. HAWTHORN, LESLIE & CO., LTD., NEWCASTLE-ON-TYNE, ENGLAND

Messrs. Peckett & Sons, of Bristol, England, and of which large numbers have been built and supplied to gas works and ironworks, to collieries for surface work, and for ordinary contractors' use. The cylinders are 10 inches in diameter, with a stroke of 15 inches, the wheels 2 feet 6½ inches in diameter, wheel base 5 feet, and weight in working order 16½ tons. This engine is for use on standard gauge lines; but smaller locomotives, some with outside cylinders, are built for use on narrow gauge lines.

Fig. 2 shows a comparatively small type of six-wheeled coupled locomotive built by Messrs. Hudswell, Clarke & Co., Ltd., of Leeds, England. Large

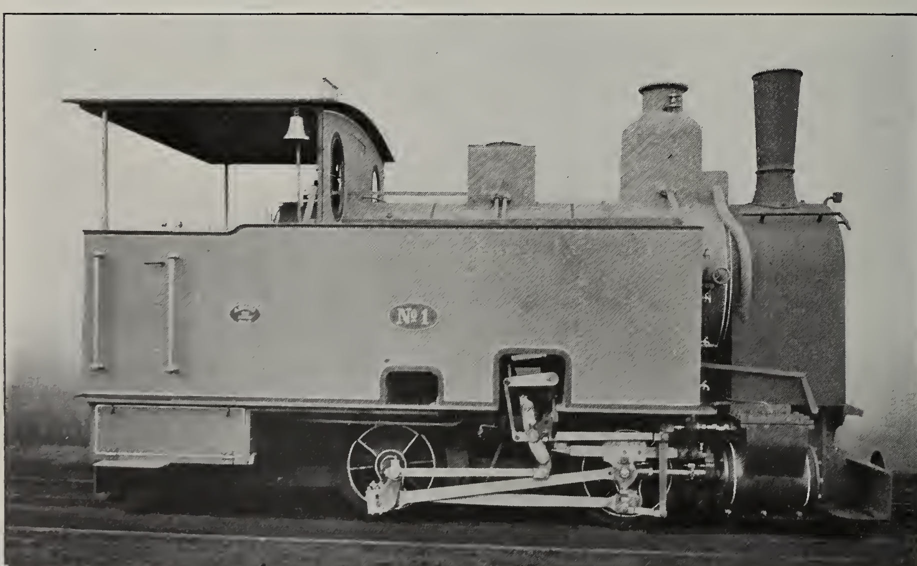


FIG. 4.—A CONTRACTOR'S LOCOMOTIVE BUILT BY A. BORSIG, TEGEL, NEAR BERLIN, GERMANY

numbers of these engines have been built and supplied to contractors, collieries, etc. This particular locomotive has cylinders 13×20 inches, wheels 3 feet $3\frac{1}{2}$ inches in diameter, and weighs in working order 24 tons.

Fig. 3 shows a larger type of six-coupled, saddle-tank engine, with outside cylinders, built by Messrs. Hawthorn, Leslie & Co., Ltd., of Newcastle-on-Tyne.

These may be taken as samples of the stock designs of British locomotive-building firms for factories, quarries and for surface use at mines of various kinds. Such locomotives are used very extensively in Great Britain and in the Colonies.

Two German designs of four-wheeled locomotives for similar general work are illustrated in Figs. 4 and 5, the one as built by the firm of A. Borsig, of Tegel, near Berlin, and the other as built by the Hohenzollern Locomotive Works, of Düsseldorf-Grafenberg.

When it is required that the locomotive shall go through passages of limited dimensons, but not such as will require special design of the locomotive as a whole, it may not be necessary to alter ordinary designs further than to fit a short chimney, to use a low steam dome, or none at all, to arrange the boiler as low as possible on the frames, and to appropriately shape the cab. Fig. 8 shows such a design, as supplied by the firm of A. Borsig for work about a Spanish copper mine. This engine is required to work into the mine when needed, and so the cab is shaped to approximately fit the passages.

FIG. 5.—A CONTRACTOR'S LOCOMOTIVE BUILT BY THE HOHENZOLLERN LOCOMOTIVE WORKS, OF DÜSSELDORF-GRAFENBERG

The writer has in his possession illustrations of a small four-wheeled locomotive, built by the Hunslet Engine Company, of Leeds, in which the cab is shaped as in the German engine shown in Fig. 8, but has no side opening, the driver having to enter from behind the engine. This ensures that the enginemen shall not, by any chance, come in contact with the sides of the narrow passages run through, or with objects which project dangerously close to the locomotive.

The steam locomotives built by the same firm for the Central London Rail-

FIG. 6.—LOCOMOTIVE BUILT BY MESSRS. ANDREW BARCLAY, SONS & CO., LTD., OF KILMARNOCK

way, London's "twopenny tube," have also curved cabs, and the chimneys, domes, etc., are also limited to fit the tunnels. These engines were used in the construction of the railway, and are occasionally sent into the tunnels even now in case of breakdown of the electric trains or for special purposes.

Fig. 7 illustrates a four-wheeled, coupled, saddle tank engine having a short chimney, a depressed driver's platform, and a cab roof on a level with the top of the tank, so as to be applicable for tunnelling work, and where height is restricted. This engine has been built by Messrs. Hudswell, Clarke & Co., Ltd. It works on a metre gauge road.

Fig. 6 shows an interesting dwarf locomotive as built by Messrs. Andrew Barclay, Sons & Co., Ltd., of Kilmarnock. For its size it is a very powerful machine and has been doing good work for several years now. Quite recently a repeat order was given for a duplicate engine. On account of the lowness of the roof of the cab the driver is provided with a seat. The cylinders are 7 × 14 inches, wheels 1 foot 10 inches in diameter, boiler pressure 140 lbs. per square inch.

Another locomotive, by the same builders, is adapted for working on either a narrow gauge or on the standard of 4 feet 8½ inches, the change being effected with comparatively very little trouble. The problem of allowing for change of gauge is solved by designing the frames, axle boxes, etc., so that the wheels can be placed either inside or outside the frames, the one position being used when the narrow gauge is to be worked over, and the other position for standard-gauge work. With the wheels outside the frames, the connecting and coupling rods work on crankpins attached to the wheels, as in an ordinary outside cylinder locomotive. When the wheels are within the frames, the axles have outside cranks for the connecting and coupling rods.

A set of wheels and axles adapted for the two uses is provided with the engine, and to effect the change it is only necessary to disconnect the rods, remove one set of wheels and fit the other set, connect up the rods again, and the engine is again ready for use, but on the other gauge. Such an arrangement saves the expense of a second engine, especially for railway contractors and others, who can use the engine on narrow-gauge construction tracks and then convert it to standard gauge during the later stages of the work.

Fig. 9 represents a rather peculiar locomotive, as built by Messrs. Kerr, Stuart & Co., Ltd., of London, for a

South American mine. The whole design is rather curious; but no specially noteworthy features, as regards this article, are included. The engine has outside dimensions of 3 feet 4 inches width, and height 6 feet 6 inches, thus enabling it to enter the "adit" and haul the waggons from the headings. The tractive power is 900 pounds, equal to a load of 35 tons on a gradient of 1

FIG. 7.—LOCOMOTIVE BUILT BY MESSRS. HUDSWELL, CLARKE & CO., LTD., LEEDS

FIG. 8.—A MINE LOCOMOTIVE BUILT BY A. BORSIG, OF BERLIN, FOR A SPANISH COPPER MINE

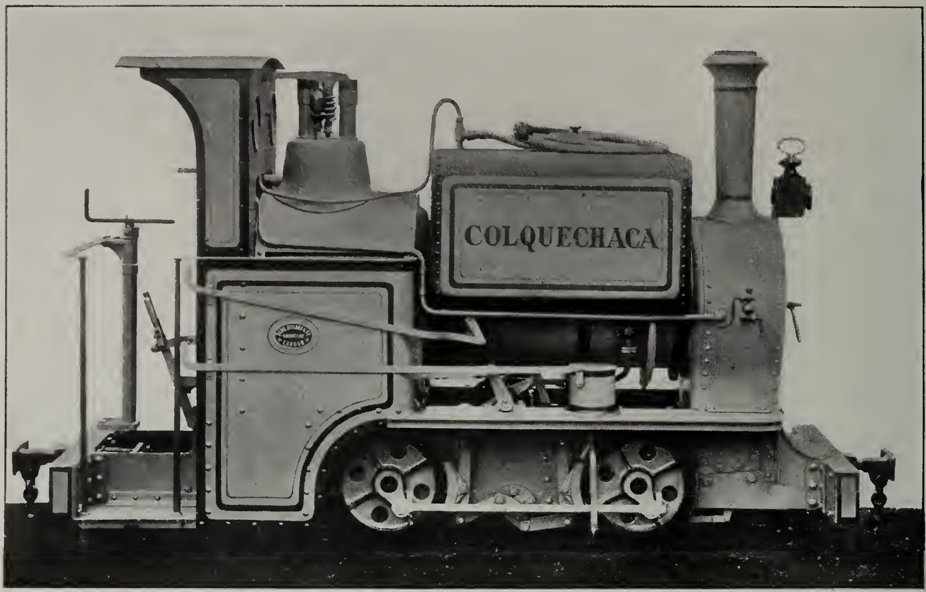


FIG. 9.—A MINE LOCOMOTIVE BUILT BY MESSRS. KERR, STUART & CO., LTD., LONDON

in 200, 20 tons on a 1 in 100 gradient, 11 tons on 1 in 60, and 3 tons on 1 in 30. The cylinders are 4½ × 8 inches, and the weight in working order, 4¼ tons. The pipe fittings on the saddle tanks provide for the withdrawal or

FIG. 10.—A COLLAPSIBLE LOCOMOTIVE BUILT BY THE HUNSLET ENGINE CO., LEEDS, AS USED IN THE OPEN

steam ejection of water from the tank for special purposes.

Considering now the designs for use in circumstances which call for radical departures from ordinary practice, Figs. 9, 10 and 11 illustrate a "collapsible" locomotive built by the Hunslet Engine Company. Fig. 10 shows the engine in its ordinary working condition as used in the open.

When required to pass through low passages, the chimney is removed and the cab lowered. A well is opened in the foot-plate, so that the driver can work comfortably in a seated position, and the engine then presents the appearance shown in Fig. 11, and has the extreme dimensions indicated in the head-on view shown in Fig. 12. While working in a tunnel, steam is turned into the water tanks for condensing, the blower being employed if required for draught purposes. The fittings on the fire-box front are arranged so that the driver can readily manipulate them in either of his working positions. Several of these engines have been built and have proved very useful for tunnel construction and like work, as they can be employed in hauling in the tunnel before it has been enlarged to its full dimensions.

Figs. 13 and 14 illustrate a collapsible locomotive built by Messrs. Hudswell, Clarke & Co., Ltd, for an iron ore mine in Spain. In this case the chimney is turned down and the cab roof altogether removed for work in limited passages. It is a small locomotive, having cylinders 5 × 10 inches, wheels 20 inches in diameter, and weight in working order only 4 tons 7 cwt. It works on a metre gauge road having rails weighing only 16 pounds per yard. The engine is fitted with condensing apparatus for use underground.

FIG. 11.—THE LOCOMOTIVE SHOWN IN FIG. 10, AS USED IN RESTRICTED PASSAGES AND TUNNELS

Fig. 15 shows a small four-wheeled locomotive recently supplied by Messrs. Peckett & Sons to the Commercial Gas Company of London for use on a line of 3 feet gauge. Its dimensions are:—height, 5 feet 4 inches, and width, 4 feet 11 inches. The cylinders are 7 × 10 inches, wheels 20 inches in diameter, and weight in working order 6½ tons.

In the United States the design of steam locomotives for use in coal mines has received considerable attention, for there are numerous collieries having "drift" shafts, allowing locomotives to

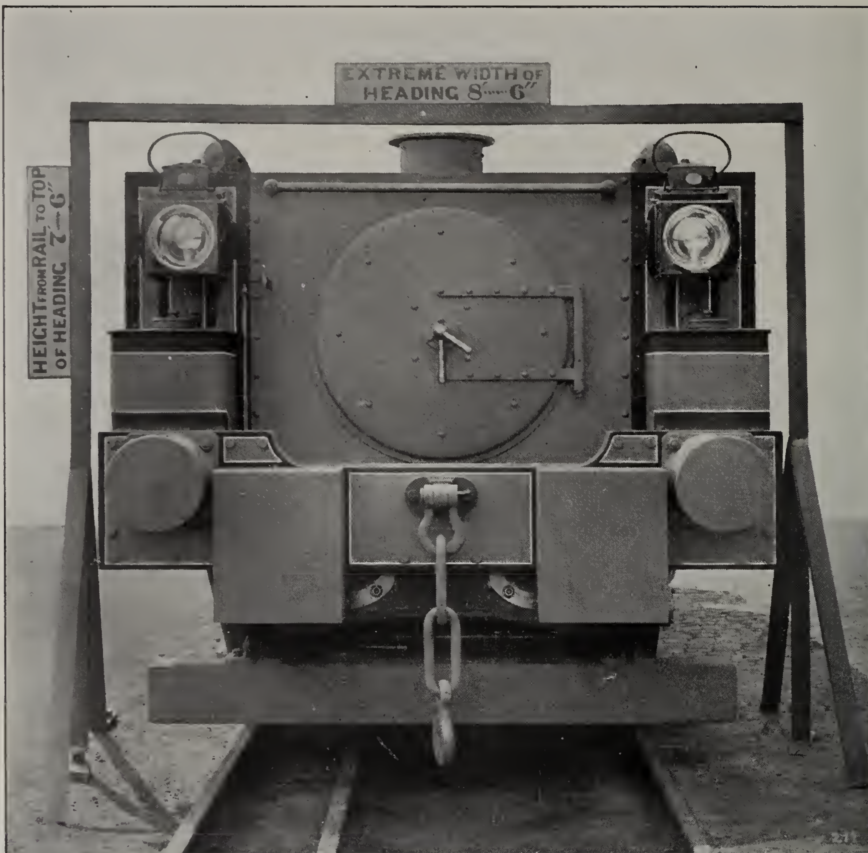


FIG. 12.—A HEAD-ON VIEW OF THE LOCOMOTIVE SHOWN IN FIGS. 10 AND 11, WITH CHIMNEY REMOVED AND CAB LOWERED

pass right into the galleries of the mine. Many exceedingly interesting locomotives have been introduced, adapted for working in very low and narrow passages. In Germany, and on the Continent generally. it is more usual to employ electric locomotives under similar circumstances. In Great Britain the use of locomotives of any kind in the mines themselves is exceptional and almost unknown.

The principal builders of these special mine locomotives in the United States are the Baldwin Locomotive Works, of Philadelphia; the American Locomotive Company, of New York; and the H. K. Porter Company, of Pittsburgh. In Figs. 16, 17, 18 and 19 representative examples, as built at the Baldwin Locomotive Works, are shown.

Fig. 16 illustrates a locomotive for the Lehigh Coal & Navigation Company, the limits for which are, height 5 feet 7 inches, and width 5 feet 4 inches. It is a four-wheeled, four-coupled saddle-tank locomotive, further interesting from the fact that, although an American engine, it has inside cylinders,—necessary in this case. The peculiar arrangement of the driver's cab should be noted. The engine is also peculiar in that the chimney does not project at all beyond the saddle-tank, and is apparently absent.

Fig. 17 illustrates another locomotive for the same company for heavier service, and which is about twice as powerful as the preceding. It differs there-

from in several respects, particularly in the use of outside cylinders and in the visibility of the chimney. It is claimed by the builders that this engine will easily pass around curves 50 feet radius.

The locomotive, illustrated in Fig. 18, for the Caswell Creek Coal & Coke Company is approximately of equal power with the engine just described, but six-coupled wheels are employed

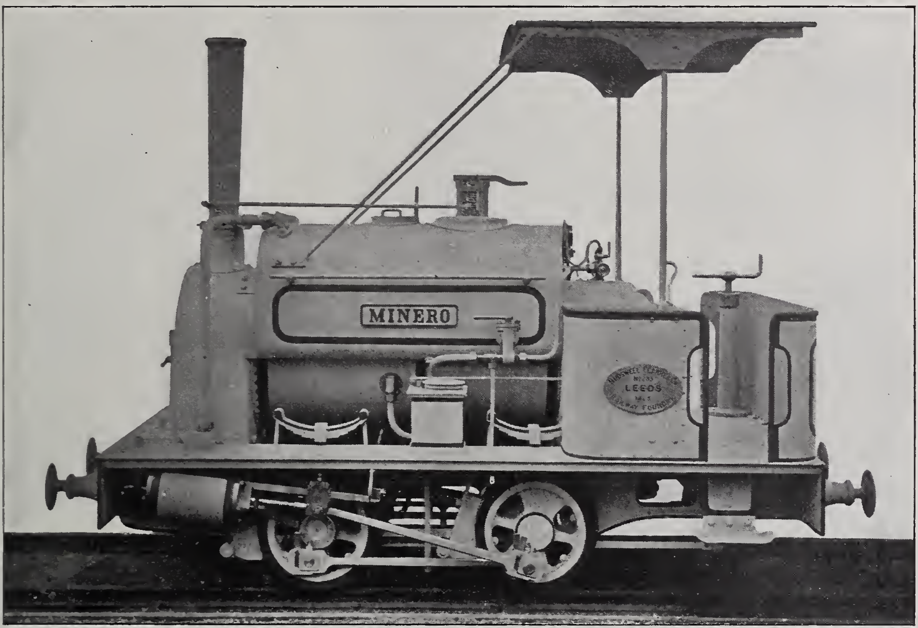


FIG. 13.—A COLLAPSIBLE LOCOMOTIVE BUILT BY MESSRS. HUDSWELL, CLARKE & CO., LTD. USUAL WORKING POSITION

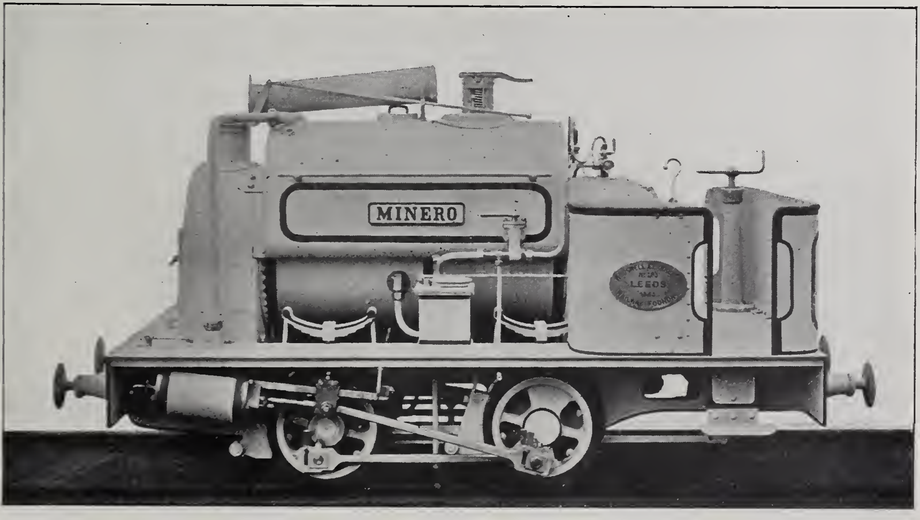


FIG. 14.—THE SAME LOCOMOTIVE WITH THE CAB REMOVED AND CHIMNEY TURNED DOWN

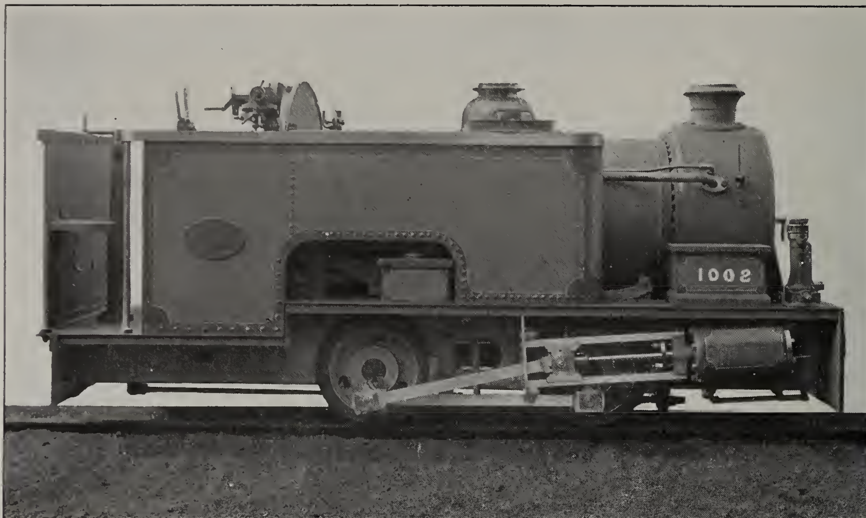


FIG. 15.--A LOCOMOTIVE RECENTLY SUPPLIED TO THE COMMERCIAL GAS COMPANY OF LONDON BY MESSRS. PECKETT & SONS, OF BRISTOL

instead of four, and an enclosed cab is provided. Six-coupled locomotives on a larger scale, and yet available for work in very restricted passages, have also been built, of which a good example is shown in Fig. 19. This engine, for the South-West Virginia Improvement Company, requires only a height of 6 feet 2 inches and an equal width. The peculiar construction of the driver's cab, the top of which is flush with the top of the saddle-tank, and the use of a chimney only a few inches high, will sufficiently indicate the difficulties which the designer had to contend with to provide a really powerful engine.

The locomotives described may be taken as examples of engines for mining service as built by the Baldwin Locomotive Works and other firms, the other locomotives for like work differing from them only in detail. It is believed also that a few have been built compounded on the Vauclain system, with a high-pressure and a low-pressure cylinder superposed at each side, the two piston

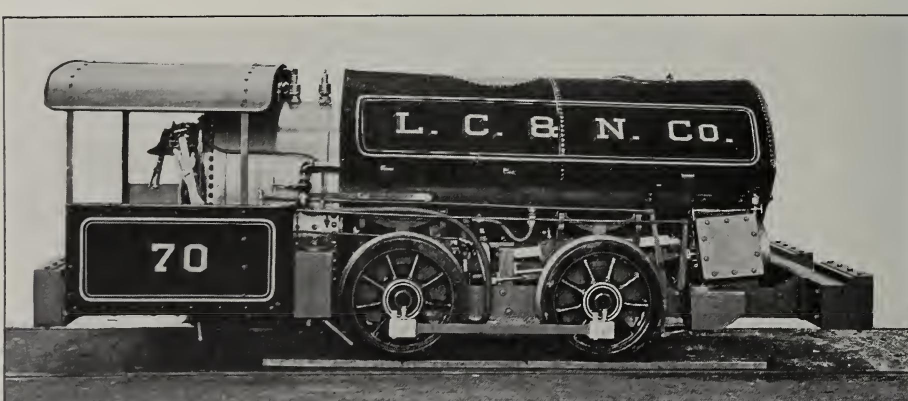
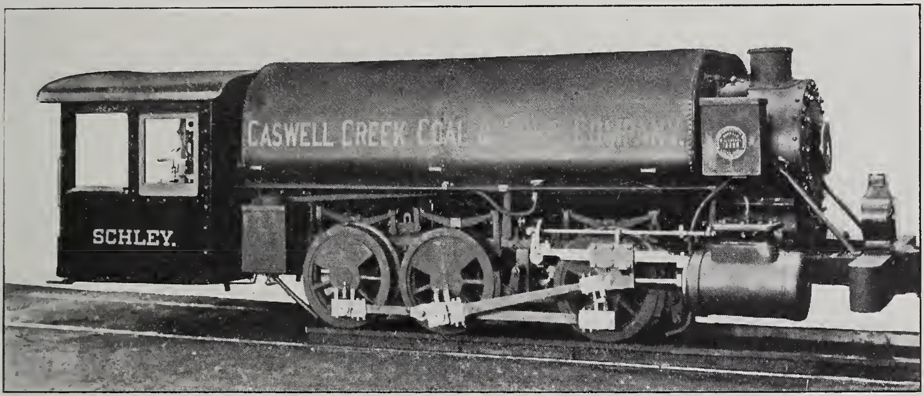
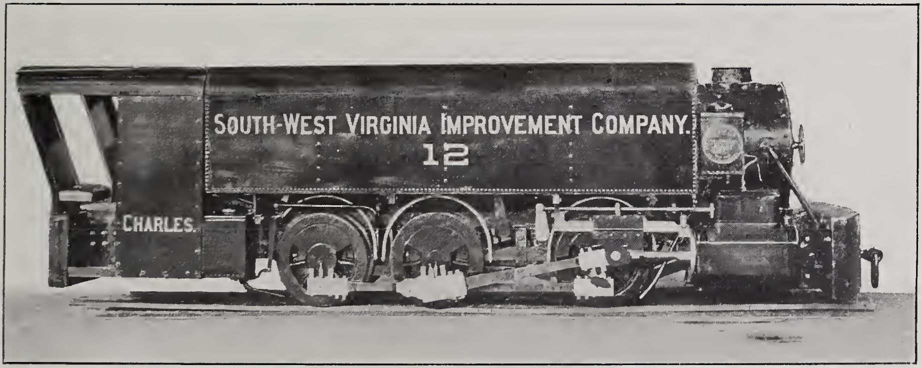


FIG. 16.—A MINE LOCOMOTIVE FOR THE LEHIGH COAL & NAVIGATION CO., BUILT BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA





FIGS. 17, 18 AND 19.—OTHER FORMS OF MINE LOCOMOTIVES BUILT BY THE BALDWIN LOCOMOTIVE WORKS

rods in each set being connected to a single cross-head, and one piston valve governing the steam ports for both cylinders. On these locomotives only one man is, as a rule, employed, and he occupies a sitting position when at work.

Before concluding this section it will be necessary to deal with "fireless" locomotives, as these have proved very suitable for use in "fiery" mines and about explosive factories and the like where the presence of fire on the loco-

FIG. 20.—A FIRELESS LOCOMOTIVE (FRANCQ SYSTEM) BUILT BY THE HOHENZOLLERN LOCOMOTIVE WORKS, OF DUSSELDORF-GRAFENBERG

motive may be a possible source of danger. They have also been used to some extent for tramway purposes, notably on some of the Paris tramway routes. In the early days of the London underground railways various " fireless " systems were proposed for the tunnel locomotives, and some of them were actually tried, though without practical success. Some of these depended on a supply of boiling water and steam under very high pressure carried in a reservoir and replenished from stationary boilers at each end of the line as required, the steam for use in the engine cylinders being obtained by reducing the pressure in the reservoir and thus causing the generation of steam. Other designs depended on " hot bricks " and various heat-retaining or heat-generating substances contained in the fire-box. The most successful of these systems, on the first-mentioned principle, and, to the writer's knowledge, the only such system in actual and successful use at the present time, is that known as the Francq system, and introduced by the Compagnie Continentale d'Exploitation des Locomotives sans Foyer, of Paris, which firm have kindly supplied the diagram shown in Fig. 21 and full particulars of the system. Fig. 20 illustrates a locomotive built by the Hohenzollern Locomotive Works on this system, and this firm have built a considerable number of such locomotives.

It is not possible, within the limits of this article, to describe the Francq system in detail, but the leading characteristics may be expressed as follows:—Steam at high pressure,—say 250 lbs. per square inch,—is supplied from stationary boilers to the cylindrical reservoir, which is about three parts filled with water. For use, the steam is obtained by means of a reducing valve at about 100 lbs. per square inch, and in consequence of the reduction of pressure the steam in the reservoir also serves for the generation of steam from the water in the reservoir. In practice it is found that the " fireless " engines can make journeys as long as are required for mining and factory work, and can stay

away from the stationary boilers for considerable periods. The reservoir is well clothed with felt and other heat non-conductors. Several of these engines are in actual use about explosive factories to the writer's knowledge, not to mention other and various uses for which such locomotives are particularly suitable.

Before completing our survey of these special steam locomotives it will be well to describe the combined locomotive and crane which is built by several firms, and which has been adopted by several railway companies for use about their own works. By this combination the locomotive can be used not only for the usual shunting and miscellaneous tractive work, but also as a transportable crane for loading waggons, etc.

In Fig. 22 a combined locomotive and crane, as built by Messrs. Hawthorn, Leslie & Co., Ltd., of Newcastle-on-Tyne, is illustrated as an example of what is done by locomotive builders in this direction. The actual engine is one used by the builders about their own works.

Several arrangements of the crane have been adopted by different builders. In some instances the crane is fitted round the chimney, such an arrangement being used by the firm of A. Borsig, of Berlin, in several engines built by them, and also at one or two English railway works. Other examples, and this is the more usual, have the crane fitted on the bunker of the engine. In most cases, too, the lifting is done entirely by means of winch

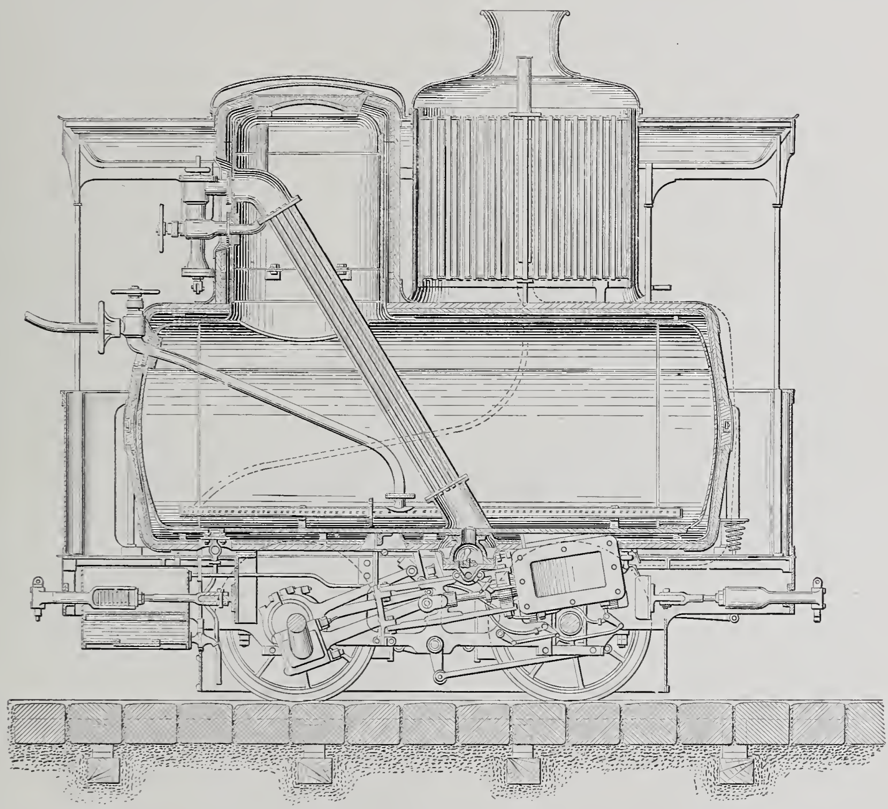


FIG. 21.—SECTIONAL VIEW OF A FRANCQ FIRELESS LOCOMOTIVE AS BUILT BY THE COMPAGNIE CONTINENTALE D'EXPLOITATION DES LOCOMOTIVES SANS FOYER, PARIS.

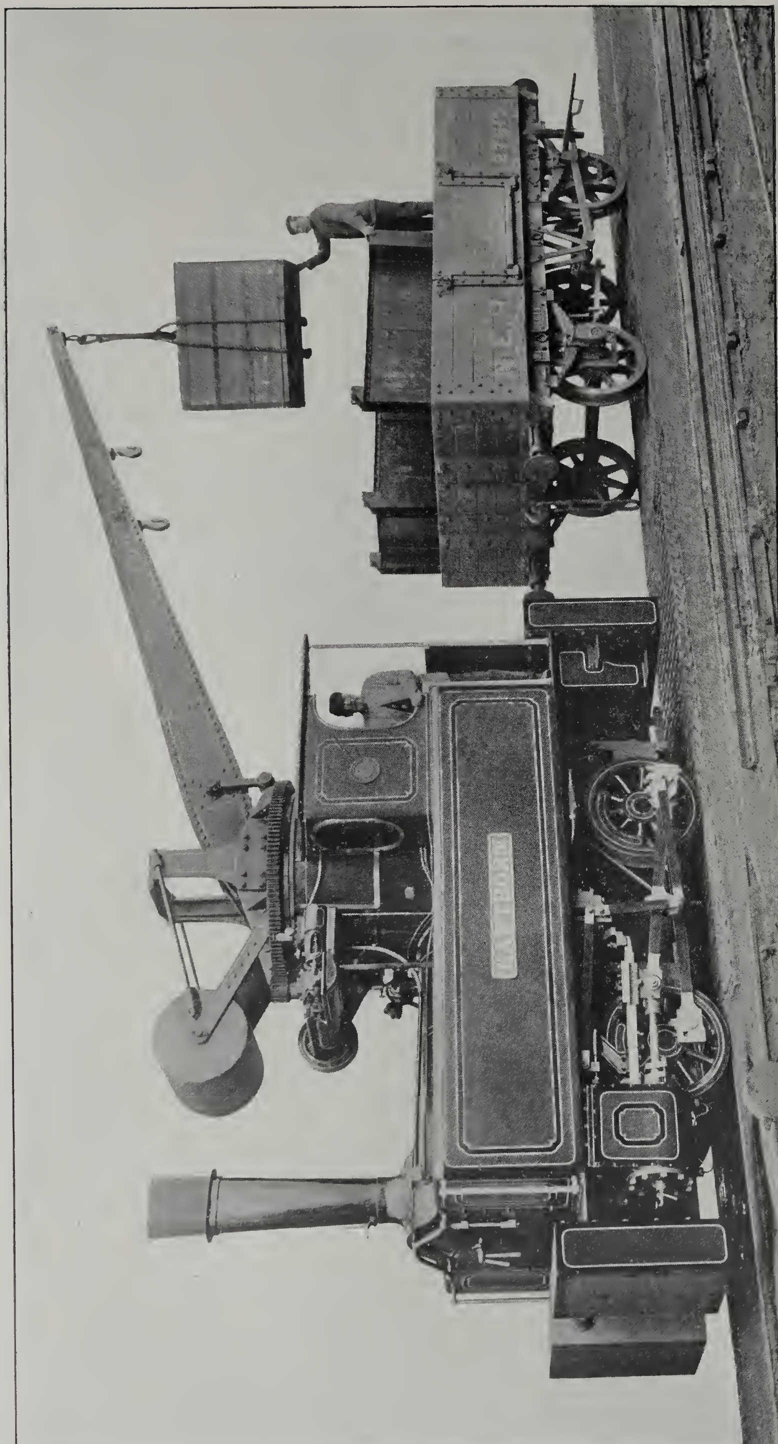


FIG. 22.—A CRANE LOCOMOTIVE BUILT BY MESSRS. HAWTHORN, LESLIE & CO., LTD., NEWCASTLE-ON-TYNE

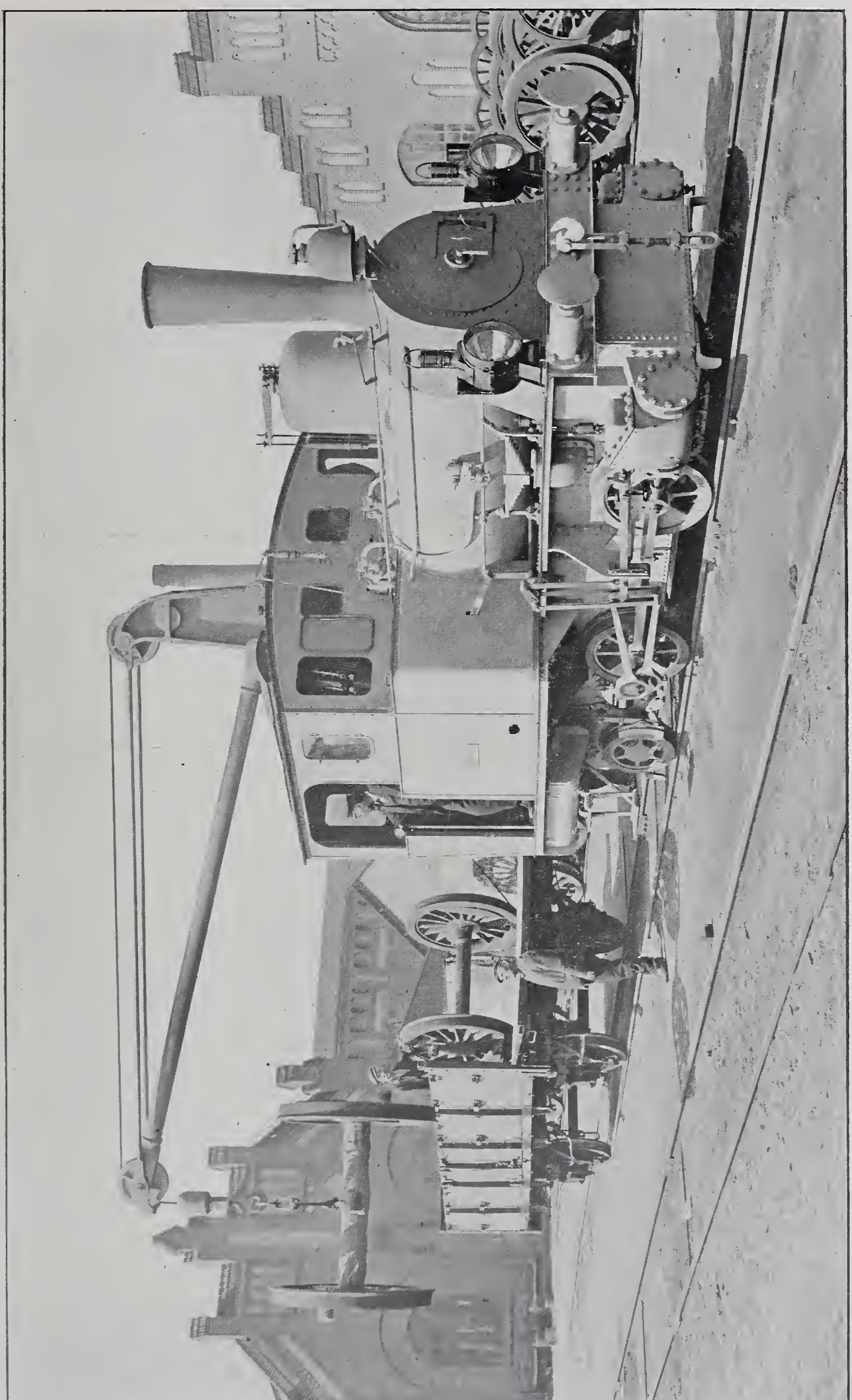


FIG. 23.—A CRANE LOCOMOTIVE BUILT BY A. BORSIG, BERLIN, GERMANY

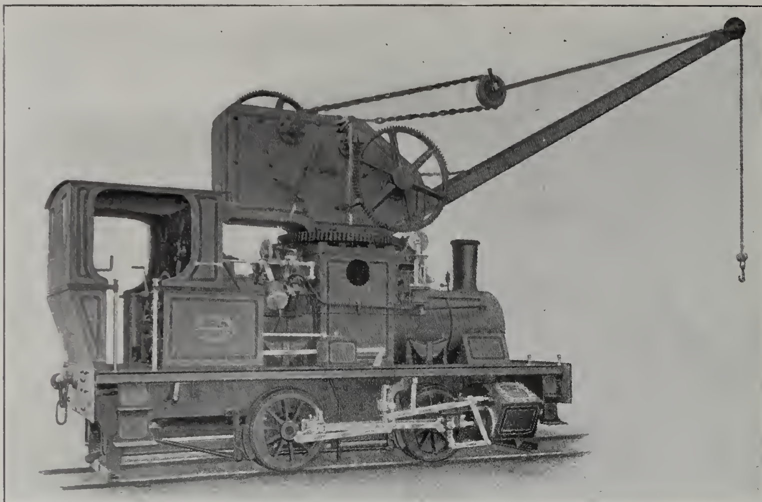


FIG. 24.—A CRANE LOCOMOTIVE BUILT BY MESSRS. ANDREW BARCLAY, SONS & CO , LTD.

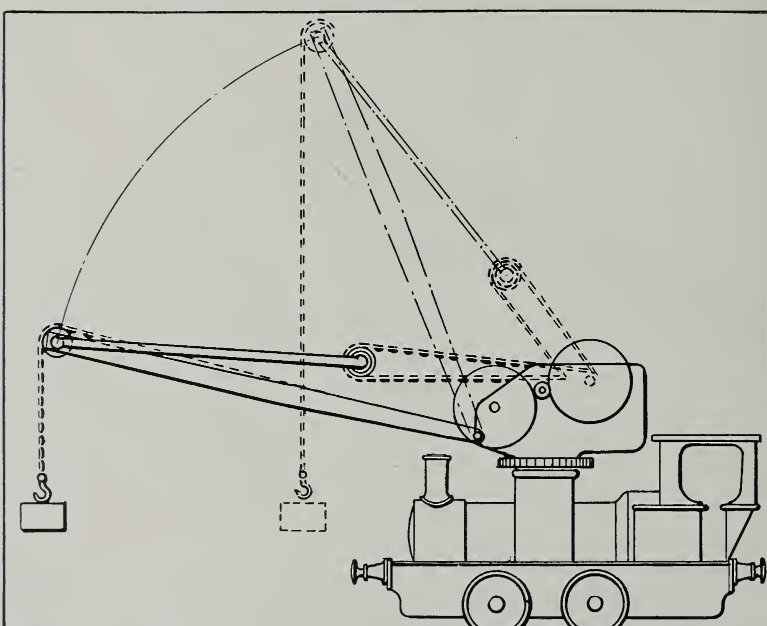


FIG. 25.—A LONG-RAKE CRANE LOCOMOTIVE BY THE SAME BUILDERS

chains, and not by the movements of the jib, as in the engine illustrated. Fig. 23 shows one of the Borsig designs.

In Fig. 24 a crane locomotive built by Messrs. Andrew Barclay, Sons & Co., Ltd., is shown. The crane is mounted on a strong base which spans the boiler, but is supported clear of it, resting only upon the locomotive framing. A massive steel casting receives the centre pivot on which the crane re-

volves, and various constructional devices are employed to insure adequate strength. The jib is of steel plates and angles, and is fitted with gear for raising or lowering its end to a variable radius and height. In this particular locomotive a maximum vertical height of 24 feet is provided for.

A two-cylinder, reversing, hoisting engine is placed diagonally near the top of the boiler and supported on the crane base. Another two-cylinder engine is placed vertically for slewing the jib right round the locomotive in either direction. This crane is capable of handling loads up to 5 tons at a radius of 12 feet, and 2½ tons at a radius of 25 feet. The locomotive is capable of travelling up to about 10 miles per hour, and can haul considerable loads. The water tanks are placed under the boiler between the frames, though side tanks are more often fitted. The coal bunker is placed at the left-hand side of the foot-plate. Balance weights are provided opposite the jib, and they are so arranged that it is not necessary to clip the engine to the rails when using the crane, as in some crane locomotives, and the rails need not be unusually heavy.

Fig. 25 shows a still larger locomotive built by the same firm. This one will swing over as many as six lines of rails, and will lift one ton at the greatest radius or five tons at the shortest radius.

Enough has been said to show that good work has been done by locomotive building firms in various countries in catering to the needs of mine owners, manufacturers and others in adapting the steam locomotive as a tractive agent on a small scale and as a machine forming part of the industrial equipment of a mine or factory. Examples could be multiplied almost indefinitely, for, besides the firms here named, other similar firms do a more or less extensive business in these locomotives.

Regarding actual users, it may be said that these small locomotives are used on plantations, about iron and steel works, in mills of various kinds, in lumber districts, about cement works, brick fields, gas works, etc., and in connection with builders' and contractors' operations, if extensive enough to require mechanical transport of materials.

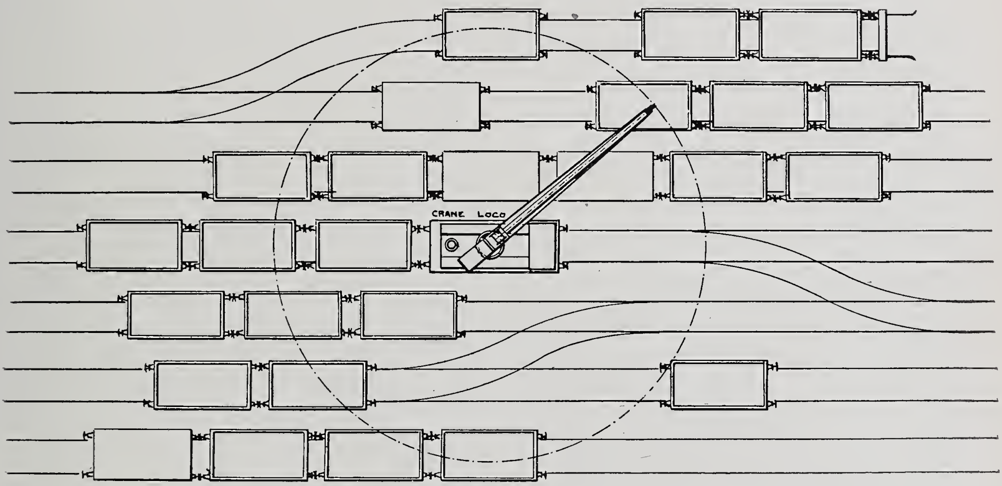


FIG. 26.—PLAN OF A RAILWAY GOODS YARD, SHOWING SCOPE OF WORK OF A BARCLAY LONG-RAKE CRANE LOCOMOTIVE

Part II of this article, to appear in the August number, will deal with Compressed Air and Internal Combustion Locomotives.

A REVIEW OF THE WAGE PROBLEM

By C. H. Benjamin

WAGES from one point of view are simply an incentive to work, and in our modern system have taken the place of the prod of the goad and the lash of the slave-driver. Two factors are important in the product of work,—quantity and quality,—and to fulfill their entire mission wages should incite to more work and better work.

The crudest system of paying employees to-day is that of daily or weekly wages, or, as we will call it, the time system. Its fatal defect is that it does not offer sufficient incentive to more or better work. Were men perfect, employers and employees alike, it would not matter very much what system were used; the man would do his best as a matter of principle, and his employer would accord him his fair share of the output. But we must take men as we find them, and long experience has shown that under a time system workmen will not do a fair amount of work, and that it is difficult under such a system to determine how much they can or should do.

The only incentive offered to the workman is the possibility that if he works well and faithfully he may attract the attention of the foreman, this may reach the superintendent, and at some future time he may get more pay.

The next step in the solution of the problem was the contract system which was in vogue in certain shops some time ago. Under this system the shop and the men were virtually turned over to contractors, who were paid by the piece for work done, and who themselves paid the men, usually a day-rate. The men were rather worse off under this arrangement than before, since the contractor was sometimes more heartless than the firm. The interests of the company and of the contractors were to some extent identical, since both wished to reduce expenses and improve methods of production. On the other hand, the company wished to reduce the contract price and the contractor wished to retain it. To prevent a reduction the contractor would sometimes nurse a job, *i. e.*, not do it as quickly as he might, just as any man who is paid by the piece might do, for, after all, he was only a piece-rate man on a somewhat larger scale.

In one case a company formerly paid men by the day. To increase production and stimulate improvements in methods it changed to the contract system. Becoming satisfied later that the contractors were making too much money, the company began to pay the men directly, so as to know better what was the cost of the work. After some time a change was made to the piece-rate system for the men, the contractors being supplanted by foremen paid by the day.

Under the new system the men received better wages, while the pay of the foremen was only about half what the contractors formerly made. Expense was decreased just as certainly as under the former system, and the company got the benefit much more surely and quickly.

Piece-rate, or paying the workman so much for each piece he makes, is the next step in development. There can be no lack of incentive here, for the more pieces made in a day, the greater the return in money. The workman becomes, to a certain extent, the partner of the company in suggesting improved methods, better machinery and reduction of waste. In reality their interests are identical, for even at a fixed piece-rate, any reduction in the time of doing a job is a saving in the general expense

of running the shop. It may not be generally understood, but it is a fact that in the ordinary machine shop the unproductive expense is equal to or greater than the wages paid the men.

The human nature of the workman made the day wage plan a failure economically. The human nature of the employer has often made an even greater failure of the piece-rate. The piece-rate is usually made too high at first, perhaps 20 per cent. less than the piece cost when made under the time rate system. In a short time the workman is found to be making twice or three times as much money as formerly. This is partly an evidence of the new incentive and partly an evidence of how much he was shirking before.

The really fair day's work is frequently from 50 to 100 per cent. more than the amount done for day-pay, the difference representing not so much increased physical labour as increased thought or mental activity. Under these circumstances the immediate temptation of the company is to cut the piece-rate. And so it goes on for a time, spasmodic increases of production by the man alternating with cutting of rates by the company, until the man finds himself straining mind and body to make just a little more money than he did under the old, careless, easy régime; or, as is more frequently the case, he sees the peril ahead, and, calculating just how he may reach the maximum wage with the least possible labour, he ceases to strive for any further improvement,—"he nurses his job."

The fixing of rates for new work is a somewhat difficult matter. Any attempt to do this by having one or two lots done on a time-rate is unsatisfactory, for the workman usually understands what is being done and gauges his time accordingly.

If it were possible to establish a fair piece-rate at the outset, and if it were possible to keep this rate unchanged (two very large ifs), the piece-work system would benefit employer and employee alike, increasing both production and wages.

Several modifications of the piece-rate plan have been suggested, and some of them are in use. In 1895 Mr. F. W. Taylor described what he called the differential piece-rate system as applied by him at the Midvale Steel Works. His method consisted in paying two piece-rates,—a high one when the job was done inside a certain specified time, and a low one when more than that time was taken.

For example, it was estimated that a good mechanic could make a certain piece in ten hours, and it was agreed to pay him $3 for each piece made inside that time. If, however, he consumed eleven hours on the job, he was to be paid only $2.70 per piece, the difference usually being 10 per cent.

There was thus the usual incentive of piece-rate, the more pieces, the more pay, and, further than that, an additional incentive of an increased rate if he succeeded in passing a certain limit.

If he made eleven pieces in 100 hours while his neighbour made only nine, he would not only get pay for two more pieces, but an increase of 30 cents per piece on the whole lot.

Mr. Taylor justifies this plan on the ground that the saving of time in shop rent, use of tools and office expense warrants the increased rate. He states that the effect of this system in the works mentioned was to double the output, and that comparatively few men failed to make the high rate. He, however, especially emphasised the fact that the critical point in the whole system is the fixing of the time-limit for each job,—that is, determining just where the scale shall change.

This is now done in the best shops by analysing each process and resolving it into its elementary operations; so much time to transport a piece, so much to clean it, to lift it into the machine, to adjust the tool, to take the roughing cut, to finish, etc., etc. All this takes time and experience, but the data collected on one job help to make estimates on the next, until the rate-fixing is removed more and more from the realm of guess-work and becomes a correct mathematical calculation.

The writer believes that the correct

and careful determination of the time it should take to do a certain piece of work is the key to the whole situation, and that once determined, almost any piece-rate system will give satisfaction.

The premium system, as it is now called, is the invention of Mr. F. A. Halsey, and has been applied on both sides of the Atlantic with good success. Unlike the system just described, the premium plan is based on a day-wage or time-rate. In other words, a minimum wage is established for each man, and he is sure of his day pay, whatever may happen. If, on the other hand, he reduces the time cost of a piece below a certain fixed limit, he is given a share of the saving while the company keeps the balance.

To use again our example, we will suppose that the man is paid 30 cents an hour, and that he is expected to make ten pieces of a certain kind in 100 hours. He receives $30 for his hundred hours whether he makes nine, ten or eleven pieces; but in the first two cases he receives nothing more. In the last event he has saved the company ten hours, or $3 worth of time. He is then paid an additional sum of from one-third to one-half of this saving while the company keeps the balance. Under the day-wage plan the company profits by any increase in production; under the piece-rate system the employee profits; while by this last system both share in the profit.

To some this sharing of the saving may seem unfair to the workman, and most advocates of piece-work claim that it is. On the other hand, it may be said that with straight piece-work there is no direct incentive for the employer to co-operate with the employee in improvement of machinery and methods, and that the workman is frequently hampered by breakdowns and poor management,—things entirely beyond his control. Under the premium system both have an interest in keeping everything up to the mark and using all legitimate means to increase the output.

Mr. Halsey and all other advocates of the premium system are very emphatic in saying that its success depends on a careful fixing of the time limit in the first instance and then a maintenance of that limit indefinitely. The only excuse for a change would be either a radical improvement in machinery or a decided depression in business. The fact that the workmen are making unusually large wages should have no effect on the limit.

As in the piece-rate system, the importance of a careful analysis of the work is manifest. The success or failure of the system will depend on the accuracy with which the time limits are determined. Mr. Halsey urges that the time limit be made a liberal one at first, and that only one-fourth or one-third the saving be allowed the men. In this way it is made possible for most of the men to get premiums, while at the same time the amount of the premiums will not be such as to tempt the company to cut the rate. The effect of a low time limit and a high premium rate is to make too sharp a distinction between the average man and the superior man and to cause dissatisfaction.

Two features of the premium system seem especially commendable. In the first place, each workman is assured of his day's wages, as much as, or more than, he could earn in other shops, and the matter of premium is entirely optional with him. There is no compulsion about it. This feature makes it possible to introduce the system without disturbance into a shop where men are paid by the day.

It would seem that this plan should commend itself to the labour unions as a reasonable solution of the wage problem. But there has been opposition to it from this source. Some labour agitators are unwilling that industry and ingenuity should receive any reward.

In the second place, the premium plan effects a division of the profit from increase of output between employer and employee, making common cause between them for improvement in methods and in machines, and also dividing any losses due to accidental stoppages, breakdowns, hard iron, etc., etc. Tables of figures have been published from

time to time showing the savings effected by the introduction of the premium system. But two of these will be summarised here. In one establishment an average of forty different jobs gives the following ratios between the old and the new, the two contracts being consecutive:—

New time	57
Old time	100
New wages per piece	75
Old wages per piece	100
New wages per day	129
Old wages per day	100

Or, to put it in another way, a saving of 43 per cent. in time and 25 per cent. in wages to the company and a gain of 29 per cent. in wages to the workmen.

A large establishment where electrical machinery is manufactured shows the following results:—

New time	61
Old time	100
New wages per piece	72
Old wages per piece	100
New wages per day	123
Old wages per day	100

The men in each case were allowed one-third of the time saved.

Several modifications of the premium plan have been put in operation, notably in Great Britain. Some manufacturers think that the incentive should diminish as the production increases, so that there shall not be the temptation to carry the increase too far at the expense of quality of the work and well-being of the workman. At one large engine works in Glasgow the percentage is determined thus:—The workman is given a percentage over his wages, the same as the percentage of saving in time. To illustrate again by an example, if the man has 30 cents per hour on a 100-hour job and does it in 90 hours, he has saved 10 per cent. in time and is allowed 10 per cent. additional on his wages, or \$27 plus \$2.70 = \$29.70. Under the Halsey plan he would receive only \$27 plus \$1, or \$28. On the other hand, if he did the work in 30 hours he would receive more by the Halsey plan than by the other.

It seems to the writer that the straight premium rate first described is simpler and will be better understood by the men. If the time limit is properly fixed in the beginning, there will be little danger of overproduction on the part of the workmen or of cutting rates on the part of the company.

It has been proposed to shade piece-rates in a somewhat similar manner by diminishing the rate as the output increases,—in other words, to let the man's wages per hour increase, not directly as the number of pieces made per hour, but as the square or cube root of that number.

The various systems here mentioned can be compared graphically better than by words, each being represented by its appropriate curve. We will let all vertical distances in the diagram on the opposite page represent wages per hour received by the workman and the horizontal distances, the number of pieces per hour made by him.

The line *ABD* represents the day-wage or time-rate system,—no incentive, a dead level of mediocrity. No. 1, the line *OP*, represents the straight piece-rate system, a uniform incentive measured by the angle *POM*, and *OM* is the rate of production assumed, or the time limit, being the number of pieces that a good workman should do in an hour.

No. 2, the line *OCP*, represents the differential piece-rate, the rate being lower and the incentive less inside the time limit, and then suddenly rising to the regular rate on the line *OP*. From this point of view the lower rate is in the nature of a punishment to the lazy or ignorant workman because he does not accomplish more. The line No. 3, or *OBP*, is that of a reduced piece-rate or diminishing incentive intended to prevent overproduction and rate-cutting.

Instead of being a broken line, this may be a curve from the start with a gradually diminishing incentive. The line *ABP*, or No. 4, is that of the premium plan, having from the point *B* a uniform incentive, and at no part of its course going below the line of average wages *ABD*. It has been aptly described as a system of rewards without penalties. The point *B* is purposely chosen to the left of the point *E* on the piece-rate line to indicate the policy of

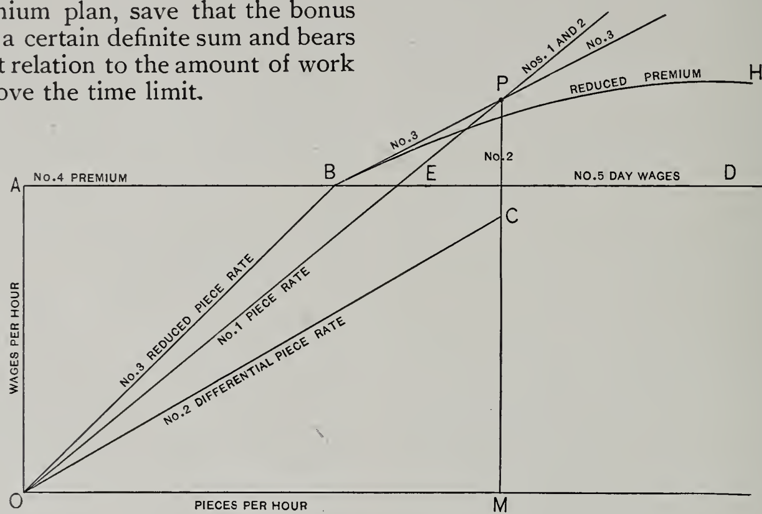
a liberal time allowance, while the line *BP* has a smaller angle, and, therefore, less incentive than *OP*. The lines are purposely arranged so as to intersect at *P*, the point of average production by good workmen.

The curved continuation *BH* of the premium line represents a system of reduced premiums, supposed to lessen the danger of the premium rate being cut.

The so-called bonus system used at the Bethlehem Steel Works is similar to the premium plan, save that the bonus given is a certain definite sum and bears no direct relation to the amount of work done above the time limit.

would be more apparent. The premium and bonus systems of paying labour reward those who are entitled to it, while any system of general profit-sharing rewards the position and not the man. Furthermore, workmen do not like to wait so long for their share.

The writer would call attention to one scheme of profit-sharing which seems to have been carefully thought out and which is in successful operation.



CURRENT WAGE SYSTEMS GRAPHICALLY COMPARED

No mention has so far been made of profit-sharing schemes since, as a rule, they have not succeeded, and because they do not seem rational or logical. The time consumed in performing certain operations in the factory and the value of those operations when completed are comparatively stable factors in the cost of production, and they are factors in which the workman has a direct personal interest. The commercial end of the business is entirely beyond his ken, and he is not in a position to participate in the purchase of material, the sale of product or the various methods of building up trade. Why should he have a money interest in things which are beyond his control and in which he has no active part? If it were possible to inaugurate a system of profit and loss-sharing, the equity of the thing

The Baker Company, a Wisconsin firm of pump and windmill manufacturers, has for its manager a son of one of the members of the firm. Believing that the employees of the company were entitled to share in the general prosperity, the young manager reorganised the company on the following basis:—$200,000 of stock was issued and fully paid up; $100,000 of stock was then issued for the benefit of the workmen. The profits of a year's business were divided as follows:—A 5 per cent. dividend was declared on the paid-up stock, this being considered the earnings of that stock; 10 per cent. of the remainder was put in a sinking fund for rainy days. The rest was then divided *pro rata* between the stockholders and the men on the basis of the earnings of each. For example, the man who earned a salary

of $1000 and the stockholder who received $1000 in dividends on his stock shared equally in the profits.

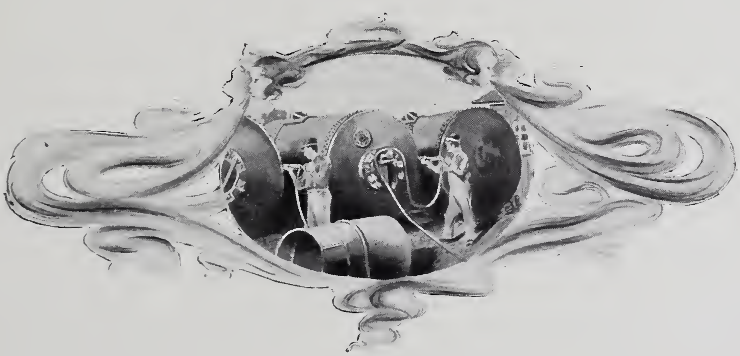
The man is thus treated as a capitalist, his capital being his strength and skill. The profits were paid to the men 15 per cent. in cash and 85 per cent. in stock. The next year they would be paid dividends on that stock before the division of profits was made.

In 1900 sixty per cent., and in 1901 eighty-two per cent. of the gross profits were left to divide between capital and labour. One machinist received in cash and stock $725 above his regular wages.

Two features in the plan just outlined are commendable,—the gradual increase of working capital by the issue of stock to the men in place of cash and the maintenance of a sinking fund for prospective hard times. For it is when hard times come that profit-sharing loses its elasticity. It would seem safer to put 25 per cent. rather than 10 into the emergency fund, limiting the fund, perhaps, to a certain maximum amount.

Neither has co-operation been mentioned as a possible panacea, for we have yet to see this demonstrated as a working proposition. The horse and the ox do not yoke well,—and too many cooks always spoil the broth.

Municipal control and other socialistic remedies may or may not affect the general public favourably; they certainly will not change the condition of the workman as a workman. It matters little to him whether he is paid by an individual, a corporation, or a municipality, as long as he is directly controlled by human beings with all the faults and weaknesses to which we sons of Adam are heirs. Salvation for him and for his employer lies in such relations as shall show both that their interests are identical, and that the Golden Rule is the best business precept.



THE CHOICE OF A STEAM PLANT

WITH SPECIAL REFERENCE TO AMERICAN ELECTRIC POWER INSTALLATION

By George H. Barrus

THE STEAM TURBINE

INTEREST in the steam plant, and in the choice of engines and boilers for electric power generation, has been widely increased by the introduction of the steam turbine, and there is no department of engineering which is receiving more attention at the present time on this account than that of steam engineering. The subject has attracted more notice than ever during the past year, and particularly on account of the development of the Curtis turbine.

No one can now discuss matters regarding the selection of a steam plant, especially in electric circles, without becoming aware that the steam turbine has obtained a strong foothold, and it must be considered, along with the various kinds of reciprocating engines, as one of the sources of steam power from which to make a selection. In this connection it is significant, as showing the trend of engineering thought and development, that one of the largest and most widely known builders of reciprocating engines has recently embarked in the turbine business, and that there are no less than four types of turbines on the market, made by responsible firms.

Until recently engineers familiar only with reciprocating engines, had great doubt as to the ability of the steam turbine to compete with a reciprocating engine in the matter of steam economy; and there are many who still cling to the belief that the turbine principle must be a wasteful method of generating power. Reports of late investigations on different kinds of turbines, made by different engineers who are wholly unbiased, leave little room for doubt, however, that the turbines in their latest and best forms are not only far from being wasteful, but, as a matter of fact, their economy in steam consumption is equal, if not superior, to that of the best classes of reciprocating engines in common use in electric power stations.

There are numerous advantages possessed by the steam turbine which are exceedingly attractive to the purchaser of a steam plant, and to the operator as well, and now that the turbine business has reached a stage of successful development, it is not surprising that the turbine manufacturers are favoured with a large amount of business. At the same time, there are points about the turbine which are less attractive than those noted, and these make the engineer question what the ultimate status of the machine will be after it has been subjected to the wear and tear of ordinary electric power plant service.

It must be conceded that the turbine is still in what may properly be termed the experimental stage, although giving promise of an excellent future, and it would be unwise, if not impossible, in a popular discussion of the subject, such as may be attempted in this article, to make a comparison of the different makes, or to offer any suggestions as to matters which should govern the choice of a turbine, in case the purchaser of a plant should decide upon this form of motive power. The purchaser himself is the only one who can settle this question, after having made a careful examination of the present status of the different types presented for a choice.

THE RECIPROCATING ENGINE

In the matter of choosing a reciprocating engine for an electric power plant,

it is noteworthy that in nearly all of the larger and more important electric plants which have recently been installed in the United States, the engines adopted are those of the well-known Corliss type. The fact is notable because the character of the motive power in these plants has been decided upon only after the most searching examination, in which the subject is studied in all its bearings and viewed from every standpoint. It is to be noticed also that not only in the newer and more modern stations, but also in the older plants of the larger sizes, the Corliss engine is the most widely used. It is probably not too much to say that in the larger stations there are a greater number of these engines driving electric generators than of all other kinds of engines combined.

The features which distinguish the Corliss engine from engines of other types are the form, arrangement, and mode of operation of the valves. If this engine is more popular, therefore, than other engines, the reason lies primarily in the popularity and success of the Corliss valves and of the mechanism employed in operating them, rather than in any other particular.

Corliss valves have many advantages which justify their excellent record. One of the advantages which is greatly appreciated by the operating engineer is the accessibility of the valves for examination and repair. Being cylindrical in shape and lying in a cylindrical chest of small diameter, the bonnets which cover the ends are of small area. Indeed, they are so small that four bolts suffice to hold one in place. To uncover the chest for the purpose of removing and examining the valve, it is necessary, therefore, to remove only four bolts, and this can be done not only with the greatest ease, but with the least expenditure of time. Another thing which adds to the ease of removal is that the valve is withdrawn from the chest endwise through the rear opening, and the connection between the driving end of the valve and the mechanism is such that the removal takes place without disturbing the mechanism in the least.

Accessibility in an engine valve is of little avail, however, unless the valve and its seat can be easily repaired. The Corliss valve is not only accessible, but its cylindrical form enables it to be most readily turned in the lathe and refitted when it becomes worn. The seat, being also cylindrical, is most easily rebored when the wear of the surface makes it necessary.

Another advantage of the Corliss valve is its durability and its tendency to maintain a steam-tight condition in service. The valves have considerable lap, and for this reason the wear of the lapping surface occurs at a slow rate, and excessive leakage appears only after a long period of service. The use of independent steam and exhaust valves, the location of the exhaust ports and valves in horizontal cylinders at the bottom where best drained, the simplicity and accessibility of the valve mechanism, and the ease with which the mechanism is adjusted, are added advantages, which, one and all, have done their part in making the Corliss engine popular among engineers, and most serviceable in practice.

The mechanical features noted are not the only ones which distinguish the Corliss engine and give it high standing. It is also most economical in the consumption of steam, and this advantage is always recognised as one of the greatest importance. The economy realised in operation is the direct result of the notable points of design which mark the Corliss construction. One of these, which takes a leading place, relates to the efficiency of the valve mechanism and releasing gear. These operate in such a manner as to secure a highly effective distribution of the steam; that is, the admission, cut-off, release, exhaust, and compression of the steam in its passage through the cylinder are made to take place at the proper times to secure the most economical work. That the distribution is well carried out, is shown by the form of indicator diagrams taken from the Corliss engine. These present such excellent features as to leave little room for improvement.

The design of the Corliss valve and its location close to the bore of the cyl-

inder, as well as near to the end of the stroke, reduce the clearance passages to small volume, and furnish another reason for the economy of the engine. Still further reason for economy is the fact, already noted, that the form of the valve is favourable to tightness, and, not only this, but to a maintained tight condition for long periods. Excellent steam distribution and small clearances are of little avail in securing economy in an engine, unless tight valves and pistons go with them, and these are not wanting in Corliss engines which are properly handled. The economy in steam consumption which is obtained by the Corliss design is well proved by actual tests in practical operation. No engine, in the writer's experience in testing, gives better records.

One of the latest designs of the Corliss engine which has been adapted to electric work, where large power is required, consists in the use of a pair of engines, each of which has two cylinders, one being horizontal and one vertical, working on the same crankpin. In these engines, which are of the compound type, the high-pressure cylinders are those which are horizontal, and the low-pressure cylinders, being the larger, are the ones placed vertically. This arrangement is especially suited to electric generators, because of the uniformity of rotation produced and the consequent uniformity of the current.

The impulses due to the working of the steam are distributed in eight parts about the circumference of the shaft, and produce an almost continuous propelling force, whereas in the simple engine there are only two impulses per revolution, and the momentum of the fly-wheel and of the rotating parts of the generator is depended upon to keep up the speed while the crank passes the two dead points. Uniformity of rotation is of special advantage in alternating-current work where a number of engines and generators are required to run in parallel.

The compound condensing engine is a type that is now almost universally selected for large central stations. Between this and the triple or quadruple expansion engine, at existing pressures, there is little choice on the ground of economy, and the greater simplicity of the former is an advantage which easily gives the compound engine first place. This class of engine requires no unusually high grade of talent for its successful operation, and it furnishes a motive power which can in all respects be depended upon.

Comparatively few modern engines, even of the larger sizes, are steam-jacketed, as the increased economy due to jacketing has often been found so small as to hardly justify the necessary increase of cost and complication. Reheating receivers are in frequent use, being chiefly beneficial in producing a greater amount of power in the low-pressure cylinder, and thereby adding to the capacity of the entire engine.

Jet condensers with independent air pumps, either steam-driven or electrically-driven, are the most popular, and the loss of steam due to using the steam-driven type is largely prevented by passing the exhaust steam through a heater and utilising it for heating the feed-water for the boilers. Superheated steam is being introduced in electric power plants to some extent, but the question of its desirability and economy as to coal consumption has not been proved with that degree of satisfaction which is convincing to all steam users.

THE BOILER

Turning from the engine question to that of the selection of boilers for electric plants, reference may again be made to what has been successfully accomplished by some of the leading power stations, for their practice in boiler engineering, as well as in the matter of engines, carries much weight. One of the first large electric power stations of any note installed in the United States,—the Albany Street power house of the Boston Elevated Street Railway Company,—built about twenty years ago under the engineering supervision of Mr. F. S. Pearson, adopted the horizontal water-tube boiler of the Babcock & Wilcox make. Four or five years

ago, when the same engineer designed the Metropolitan Railway Company's power station in the city of New York, Babcock & Wilcox boilers were again adopted. In the Manhattan Railway Company's station at Seventy-fourth Street and East River, New York, which began operations two years or more ago, no less than 32,000 H. P. of these boilers are in use under one roof. Other large stations recently erected, and some in process of installation, to say nothing of many smaller plants, have adopted boilers of similar make. Whatever merits may be possessed by water-tube boilers of other makes, or indeed by any type of boiler, it appears certain from this array of examples that the Babcock & Wilcox boiler has characteristics which entitle it to no small consideration for use in electric plants, and a purchaser cannot go far astray if he makes this his choice.

The reason for the wide use and evident adaptability of this form of water-tube boiler to electric work is not found in any one conspicuous merit, but, as in so many other successful appliances, it must be attributed to the "all-around" satisfaction which the boiler gives in service, and the fact that it successfully meets the varied requirements of electric power stations.

In the matter of withstanding the high pressures which the steam engine practice of the day demands, there is little question in the mind of either the owner or the engineer that this boiler has the highest degree of safety.

The largest shell which is commonly exposed to pressure is only 42 inches in diameter, this being the steam drum, and no difficulty exists in making it of ample strength. What is of greater importance, this shell, being removed from the direct action of furnace heat, is free from the special deterioration to which boilers are subject which have riveted plates exposed to the fire; and the need of reducing the limit of safe pressure as the boiler grows old does not exist to that extent which is experienced in externally-fired shell boilers.

The boiler in question is of simple design and construction, and there are no points about it which are not readily comprehended by the ordinary fireman and engineer. Absence of complication is of the greatest importance where such rough usage occurs as that going on in connection with boiler operation. In the care and daily handling of the boiler, it does not require to be favoured, for it responds to any demands put upon it, however strong the draught and however much the fires are forced. When called upon to do so, it develops far beyond its rated capacity in power. The area of the surface at the water-line is so large that no unusual attention to the supply of feed-water is required, and the water-tender has an easy task in avoiding either high water or low water.

Every necessary provision exists for keeping the heating surfaces clean either of soot or of scale. The former is accomplished by blowing the exterior of the tubes with a steam jet, and the latter, by scraping or otherwise cleaning the interior. When the tubes wear out, they can be readily replaced with new ones, and the feature of easy repair in this respect is one of the strong points appealing to the operating engineer.

The tendency in the design of modern power stations is in the direction of using large-sized boiler units, and the boiler under consideration meets the demand. Units of 500 H. P. are widely employed, this size being about as large as it is convenient to use with the ordinary arrangement of grates, which become more and more unwieldly as the size increases.

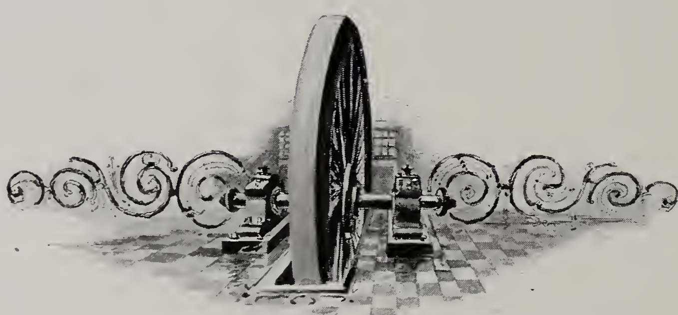
No boilers in the large modern power stations are thought to be complete, unless fitted with automatic stokers and coal-handling machinery. When the stoker is of good design and properly attended, it not only saves fuel, but if used in connection with coal conveyers, it also saves a part of the boiler room force of firemen and labourers. In large stations, where the problem of labour is apt to be a serious matter, such aids are not only desirable, but well-nigh indispensable.

Another adjunct to the boiler plant which is found in most of the large central stations is the apparatus commonly

called an "economiser," placed in the chimney flue, for heating the feed-water. The utility of the economiser depends, to some extent, on the temperature to which the water is first raised by the drips and the steam exhausted from the auxiliaries.

Under the most unfavourable conditions, however, the advantage derived from recovering the waste heat of the gases is sufficient to make a considerable saving of fuel, and the money value of the saving represents a profitable return on the investment, except in localities where low-priced coals are available.

In closing this article, the writer would not have it understood that because the particular types of reciprocating engine and water-tube boiler named are so popular and successful for electric work, they should necessarily be selected by the purchaser of a plant if he would insure satisfactory results. The desirability of other types of engines and boilers cannot thus be underrated. The fact is that many electric plants are in successful operation in which the engines have not the least resemblance to a Corliss design, and the boilers are of such different types from the horizontal water-tube class that they would hardly be recognised by a layman as being designed for the same purpose. Just what engines and boilers, and the various appurtenances which go to make up the complete plant, should be selected in any particular case can be decided only after all the circumstances are fully considered.



OXYGEN FROM LIQUID AIR

By Eugene C. Foster, M. S.

POURING OUT LIQUID AIR

FROM the time when liquid air in quantities became a reality to the present moment the unvarying question of the practical man has been, " For what can it be used ? " He has listened with interest to every statement made about its properties; he has looked wise when an explanation which he did not understand was offered him as to the process of its manufacture; he has even dipped his fingers into its boiling, bluish depths, to make sure that it did not hurt him; but at the end of every demonstration he has come back to his query, " What can we actually do with it ? "

The answers to the question at first consisted of timid suggestions that perhaps it might be used in this and that place, or might find a limited field in scientific research. Then the answers grew a little stronger and claims were made a little broader; then, almost at a bound, liquid air leaped into mighty prominence, and became the alluring promised solution of our most pressing mechanical and other problems. It is not difficult to recognise the forces at work during this period; shrewd speculators found it to be a name to conjure with, the public grew interested and asked for still more promises; they received the promises, invested in the stock of liquid air companies and waited. There is scarcely need to tell again the story which is so old; it will all be told again as soon as another claim is made for some new scientific discovery or invention.

When the investments failed to yield dividends, and the business of so-called liquid air companies began to assume a strictly legal aspect, those whose faith had been pinned to the new material began to clamor for the practical results of experiments which had been widely described; and when these failed to materialise, investors and others more fortunate allowed the pendulum to swing to the opposite extreme and declared that, after all, liquid air was but a scientific toy.

There the matter rested for a time; and in this its history is not different from that of a hundred other inventions and discoveries. Beyond this point we may with profit briefly outline some of the developments which have taken place in the United States looking toward the practical utilisation of liquid air in the industries.

Certain problems have, from the first, faced those who have sought to find a market for liquid air or its by-products; perhaps the chief of these has been the difficulty in storing and transporting the material. The best container we have to-day is one that we have had for several years,—the Dewar bulb or flask. Notwithstanding numerous experiments these bulbs have thus far been made suc-

cessfully only in glass, and while their usefulness as storage reservoirs is not questioned, they, nevertheless, fall far short of meeting the needs of the situation. They are fragile; hence they are unfitted for general use or for transportation, as the cost involved by breakage is prohibitive in most lines. With no suitable container, the experimenter has been confined to the double problem of finding a use for liquid air which shall be local and immediate. These restrictions at once eliminate a great number of possible uses to which liquid air might be put. Said a scientific man of world-wide fame one day:—

"No use for liquid air yet! Why, I think I could suggest a half-dozen practical uses within a half-hour."

Six months have passed, and he has not yet named one.

True, any number of ways have been suggested in which liquid air might be used, if not too expensive; but in nearly every case it has been found that some other agent can hold the field at a smaller cost. This precludes the use of liquid air in any way proposed, unless it will do the work better than the cheaper agent.

Comparatively early in the history of liquid air the suggestion was made that it might prove to be a convenient source of oxygen gas. Without entering into the discussion and experiments which this suggestion provoked abroad, it is proposed here to outline briefly what has been accomplished in a practical way along these lines in America. Raoul Pictet, while in the United States, evoked a great deal of interest in this subject by his experimental work and by the published reports of his labours, and when these are read it must appear evident to every one that he had large faith in the ultimate working out of the problem of producing oxygen from liquid air. Indeed, he designed an expensive device which was intended to be used in the practical production of oxygen from this source on a large scale.

Notwithstanding all that was said in favour of the project, and in spite of Pictet's experiments and those of others, little was done toward the actual manufacture of oxygen from liquid air until the fall of 1902. At this time the plant of the Columbia Liquid Air Company, at Washington, D. C., was placed under the charge of the writer and the chemical side of the problem was attacked. Here was a plant with a possible output of 120 gallons of liquid air per day,—a large quantity as a daily supply,—and there were two things to be done:—One was to make the necessary chemical investigations to determine just what amount of oxygen was available, and to so run the plant as to increase this amount; the other was entirely a business proposition,—that is, to determine whether this oxygen had any value over and above that already furnished, and to cause the public to see it if this were so. Preliminary experiments satisfied those in charge that it was entirely feasible to produce oxygen from liquid air, and that for certain purposes this oxygen would have a value in excess of that produced by other means. From this point the two propositions above referred to, with their sub-divisions, have been worked out simultaneously.

Before proceeding with a statement as to the results obtained, it might be well for a moment to consider the uses to which oxygen gas is put, and the methods of production which largely prevail at this time. A crude, unpurified article has found a large use in the past as one of the gases for use in the oxyhydrogen flame, compressed oxygen and compressed illuminating gas being furnished for the so-called calcium light and for a powerful heat over a limited area, as in the working of platinum. The calcium light, however, has gradually been displaced for many purposes by the electric arc light, and the future is likely to witness the more general introduction of the latter at the expense of the oxygen using light. This, then, may be looked upon as a somewhat declining trade.

There are many uses to which oxygen is put in manufacturing industries; yet in not one of these does its use assume a proportion which would justify its very extensive production. Numerous in-

dustries await the advent of a cheap oxygen which may be used with advantage in place of ordinary air; but for these purposes the oxygen must be so extremely cheap as to hardly justify the cost of handling the gas, or storing or carrying it, even if its initial production were secured for almost nothing. In the cement industry, for instance, it has been said that oxygen at twenty-five cents per thousand cubic feet would be worth considering; but the cost of first production would have to be extremely small to justify the added cost of handling or storing within this limit.

There is, however, another use to which oxygen has been put, which is worthy of more than brief mention; this is its use as a therapeutic agent. Presumably a gas of unquestioned purity would be demanded by those who would administer it to patients to prolong or save life; in practice, but little question has been raised until lately about the purity of the product furnished for this purpose. The amount of oxygen used in this manner is, in the aggregate, very large. Attention has not been drawn to it to any great extent because so little is used at a time. Those whose eyes have looked longingly for cheap oxygen have had in mind its use in the industries, where it would displace air, and where the quantity called for would be enormous; but those who have actually offered it for sale have found a surprisingly large demand for the product for medicinal purposes.

Outside of the liquid air process for the production of oxygen, two methods largely prevail in the United States. One of these is the Brin process, in which barium oxide is heated until it absorbs oxygen and becomes dioxide, after which the dioxide is further heated until it loses the extra atom of oxygen which it picked up, and this is collected as a free gas. In the other method, which is in almost universal use among small manufacturers, potassium chlorate and manganese dioxide are heated together until the chlorate is decomposed and oxygen is liberated. As medicinal oxygen has been furnished for local use in most cases by small plants, this latter process has turned out the bulk of the oxygen intended for therapeutic purposes in the great centres where its value has become widely known.

For the production of a high-grade gas for inhalation the chemical process is the least desirable, yet the one most largely used. The gas so made may contain an appreciable amount of chlorine or oxides of chlorine. For the elimination of these, dependence is entirely placed upon an alkaline solution, frequently of unknown strength, and in all too many instances no final test as to freedom from these impurities is made before the gas leaves the factory. This has been a source of real danger, unappreciated by those who have directed the administration of oxygen to persons whose lungs are weakened by disease. This criticism does not apply, of course, to those who have manufactured this gas under the direction of skilled chemists, and who have recognised the safeguards that should be thrown about an agent intended for therapeutic uses.

Whether made by the Brin process or by the chlorate method, oxygen gas is collected in gasometers and is then pumped into cylinders under pressures varying from 200 to 1800 pounds per square inch. Just here is another source of contamination, for all gas so pumped comes into contact with more or less of the oils used for lubrication; minute particles of these oils are carried forward into the cylinders, there to taint with their odour that and subsequent charges of gas.

All these things were taken into consideration when liquid air was being examined as a possible source of oxygen, and the determination was reached that no better source of oxygen for medicinal purposes could be obtained than liquid air, and that incidentally there would be a justifiable margin of profit in the manufacture of oxygen for certain commercial purposes.

Liquid air, when freshly made, may contain anywhere from 20 to 50 per cent. of liquid oxygen; in the latter case it should hardly be called liquid air, as the proportion of oxygen is so at variance with that in true air. It becomes

necessary, therefore, to select a method of manufacture or modify a method already introduced so as to produce the largest quantity of liquid oxygen per horse-power expended. On this will depend largely the practical working-out of the problem. With one type of liquefier the resulting product will contain about 30 per cent. oxygen; with another form, the liquid air will contain 50 per cent. oxygen. There are indications that the experience so far gained will eventually raise this percentage even higher. With liquid air once made, the question arises as to how much liquid oxygen of a certain degree of purity can be secured from a given quantity of raw material. This will depend not alone upon the amount of oxygen present at the beginning, but also upon the total loss in weight of oxygen and nitrogen in the fractional distillation to which the crude product is subjected.

The term "fractional distillation" should not be accepted in its usual significance, however. The meaning of this term, as ordinarily used, is best exemplified by the separation of such a mixture as alcohol and water. These two liquids, with a difference in their boiling points of approximately 22 degrees C., may be mixed and placed in a flask, the temperature gradually raised, and at the point at which alcohol (the more volatile liquid) boils, a vapour will come over and may be readily condensed. From this point until the temperature of boiling water is reached vapour will continue to come over; it may be condensed and caught in several receivers, each of which is designated to receive that which has come over between certain degrees of temperature.

We may at the end of the process have five receivers, containing five "fractions" of the original solution; each will contain some alcohol and some water, but the first fractions will contain an excess of alcohol and the later ones an excess of water. By repeating this process,—that is, by reboiling each fraction and collecting the condensed vapours in marked receivers, we may finally secure a practical separation of the two liquids, the alcohol being confined to the first bottles, and the water to the last. Liquid air, with its two liquid constituents, oxygen and nitrogen, having different boiling points, may be similarly treated.

It is evident, however, in the above process that we make use of the fact that we may readily secure vaporisation and condensation; while when liquid air is used we have but one vaporisation available, as there can be no second condensation to the liquid form without too great cost. Hence, such separation as is effected must be had upon one evaporation; necessarily, some oxygen will be evaporated in the effect to get rid of the nitrogen, and the success of the process largely depends upon securing a minimum loss of the former. Given two samples of liquid air, equal in weight and consistency, the method of evaporation will determine whether half a gallon of liquid oxygen will be secured,—so much will depend upon the rapidity of evaporation and other factors.

Having secured the liquid oxygen of proper percentage, this is poured into a steel cylinder tested to a high pressure, and the liquid is allowed to gradually assume the gaseous state. This will produce a pressure in the filling device, and this pressure may be regulated to a nice degree by drawing off the gas at will; under its own pressure, therefore, the gas may be forced into cylinders, which are immediately ready for the market.

Having entered this field with the production of medicinal oxygen specifically in view, certain special precautions are taken in the preparation of the product. In the first place, all air which enters the compressors, previous to liquefaction, is sterilised at a high temperature. Advantage is taken of the fact that air becomes extremely hot when greatly compressed, and this heat is augmented by outside agencies. In the second place, the liquid oxygen when obtained is carefully filtered through materials of proved value, in order to entirely remove every trace of mechanical impurity. Such impurities at this

stage will be in the solid form very largely, and a mechanical filtering process is, therefore, effective in their removal. For obvious reasons, a degree of purity is reached here which it is almost impossible to attain when impurities must be removed in the gaseous state. Again, frequent tests are made by chemical means in the course of the work to assure the securing of oxygen of a definite percentage; in this way uniformity of product is obtained, and the diluent left is nitrogen, as pure chemically as is the oxygen itself.

No estimate of comparative cost of production is warranted at this stage of development. Necessarily, the last eighteen months have borne the cost of initial experimentation, and no one who is at all familiar with the present methods of manufacturing liquid air will assume that its lowest cost has been reached. Indeed, it is the consensus of opinion among those who have had any practical experience with its production that our present methods are wasteful and costly in the extreme. Notwithstanding this fact, the results obtained have justified those who are now engaged in the manufacture of oxygen by this process in investing large sums of money in the extension of plant and business. Certainly all the cost of pumping oxygen by the old process is reduced to a minimum, for it pumps itself; and in getting rid of the oily pumps a very objectionable source of contamination has been removed.

It is clear that those who have entered this field have had in mind the production of oxygen mainly for therapeutic purposes; this being the case, a great deal of attention has been given to the manufacture of an article of unquestioned purity. Steps in the process which are costly and time-consuming may be left out entirely if only a commercial grade is to be made. The demand for the high-grade material for physicians and hospitals has practically precluded the careful working out of the problems connected with the production of a very cheap oxygen, not necessarily chemically and bacteriologically pure.

With one exception, the production of oxygen constitutes the only practical daily use of liquid air in America at the present time. This exception is in the case of its use as an agent in the treatment of cancer and a multitude of skin deformities. Numerous results of undoubted value and permanence have been recorded at the hands of those who are carrying on this work in the city of New York, and the attention of the medical profession and the public at large is being focussed upon these efforts.

WARSHIPS WITH SIX PROPELLERS

SOME EARLY RUSSIAN TYPES

IN the February number of this magazine brief reference was made to some comparatively early types of warships with four and six screw propellers, among them some circular Russian ironclads. Of two of these, the *Novgorod* and the *Admiral Popoff*, illustrations are given on pages 327 and 328 of this issue, reproduced, together with the following particulars, from a book entitled "The Warships and Navies of the World," by Chief Engineer James W. King, U. S. N., retired.

The vessels here shown were probably the earliest types of multi-propeller ships, and, like the four-screw gunboats of the United States Navy previously described in these pages, were practically floating batteries, intended only for service in shallow waters. During the war of 1877 with Turkey, they were ordered to sea for a few days' trial, which demonstrated their unfitness for rough-water service. Their circular shape also made them ill-suited for ready manœuvring, and eventually they were put out of commission. To quote Chief Engineer King:—

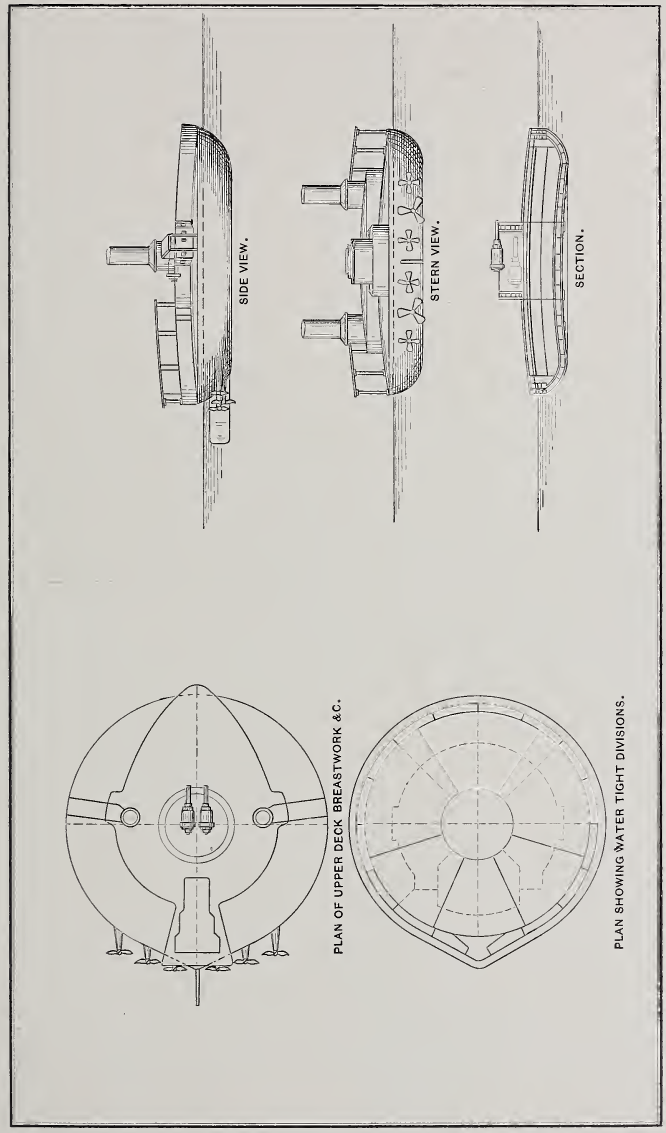
"The vessels were circular only in one sense, *i. e.*, their horizontal sections only were circular, or, in other words, they had circular water-lines. The departure from a circle was a small extension or protuberance at the stern for the purpose of facilitating the arrangement and working of the rudder and steering apparatus. It followed as a consequence from the circular form of water-line that all the radical sections were alike, the bottom of the vessel being an extended plane surface, connected with the edge of the deck by a quadrant of a small circle. With this form of section great displacement is obtained in moderate draught of water. The deck was formed in section with such curvature as to give in a ship 100 feet in diameter a round-up of about 4 feet.

"The *Novgorod* and *Admiral Popoff* had extensive unarmoured houses erected above the armoured decks. The chief of these was a spacious forecastle, which added greatly to the buoyancy forward when the sea rose there upon the vessel. Mr. Reed did not believe that even circular vessels of very low free-board could be steamed against a heavy head sea without such a forecastle, more especially when driven at high speed.

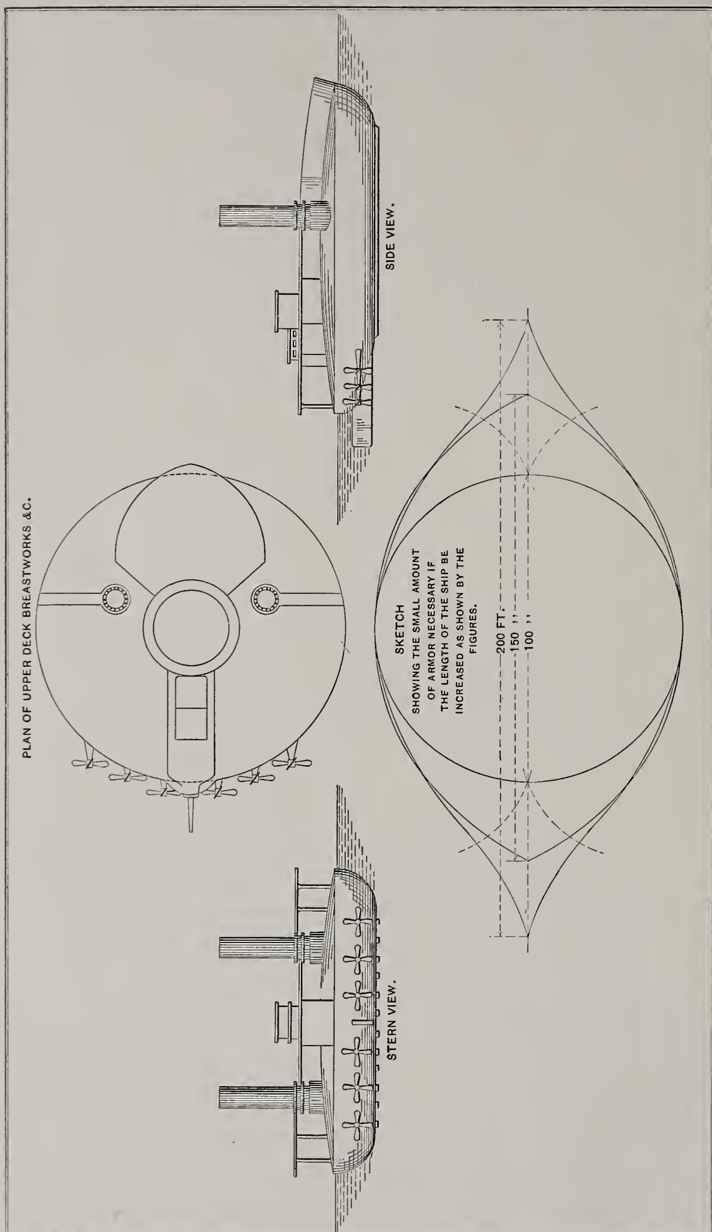
"For a sea-going citadel, viewed as a citadel only, apart from other features, Mr. E. J. Reed, the designer of the vessels, thought that the circular form was best, because it required a minimum amount of armour to protect a given area or volume, or, in other words, a given amount of armour secured the greatest amount of buoyancy. For special purposes some modified form might be preferable; but speaking generally, he thought that the circular form was best for floating armour to protect an included space, and also for giving that all-round cannonade with guns which is so desirable at sea."

Although Mr. King had not seen either of the ships, he reached the conclusion from an examination of a completely equipped model of one of them and from drawings, that simply as floating batteries they did possess some of the advantages claimed for them, but that there were also a number of objectionable features.

The *Novgorod* had a central, open-top, fixed turret with a revolving platform inside, upon which the guns were mounted *en barbette*. While the barbette principle affords very considerable lateral range as it was here applied, it leaves the guns and their crews fully



PLANS AND ELEVATIONS OF THE "ADMIRAL POPOFF"



PLANS AND ELEVATIONS OF THE "NOVGOROD"

	Novgorod ft.	Novgorod in.	Admiral Popoff. ft.	Admiral Popoff. in.
Extreme diameter	101	0	121	0
Diameter of flat bottom	76	0	96	0
Depth in hold at centre, from underside of beam to the top of the frames of the double bottom	13	9	14	0
Draught of water forward	13	2	12	0
Draught of water aft	13	2	14	0
Draught of water, mean	13	2	13	0
Height of barbette tower from load water-line	12	0	13	3
Diameter of Barbette tower, outside	30	0	34	0
Height of upper deck at side, from load water-line amidships	1	6	1	6
Height of armuor on side above water	1	6	1	6
Depth of armuor below load water-line amidships	4	6	4	6
Thickness of armour on sides (including equivalent thickness for the hollow iron girders behind armour)		11	1	6
Thickness of armour on lower strake		9	1	4
Thickness of armour on Barbette tower		11	1	6
Thickness of deck plating		2¾		2¾
Displacement in tons		2,490		3,550
Area of midship section, in square feet		1,170		1,416
Engines, nominal horse-power		480		640
Coal supply, in tons		200		250
Propellers, screw, in number		6		6
Complement of officers and men		110		120
Armament, breach loading guns:				
Two in number, each weighing in tons		28		40
Smaller guns in unarmoured breastwork				4

exposed to the enemy's fire. On shore, artillery officers rarely, if ever, mount guns *en barbette* near the level of the water, where serious and close action is expected. The practice is to secure a high and somewhat distant position, where the advantages of an all-around lateral and plunging fire are available, and where the exposure of the men and the guns is reduced to a minimum.

With a view to remedying the above mentioned disadvantages, the *Admiral Popoff* had her guns mounted on the Rendel disappearing principle. However, this change was only a partial remedy, the disadvantage of the open-top tower slightly above the level of the water still remaining.

Another objection was that the side-armour plates did not extend deeper below the water-line than in ordinary vessels, and as the *Admiral Popoff* was 121 feet in diameter, a large target was at all times presented for under-water attack by torpedoes, instead of the bow or stern alone, as would often happen in the attacks on other vessels.

Still another objection consisted in the complication of the motive machinery. There were six screw-propellers, operated by three sets of engines. Two of the propellers had diameters greater than the draught of the vessel, the periphery of the blades extending below the keel. These two screws were three-bladed, and were not worked in shallow water. Chief Engineer King had considerable experience on the Mississippi River during the American Civil War in building and operating the machinery of some wide, flat-bottomed gunboats provided with four screw-propellers, and there became intimately acquainted with the drawbacks of complication of machinery as present in this case. The screw-propellers of the Russian ships were, moreover, unprotected from attacks of any kind.

The most serious objection to the circuiar form of ship consisted in the great power required to drive a vessel, say, of 121 feet diameter, through the water at a speed equal to that of an ordinary vessel of the same carrying capacity, the weight and space occupied by the machinery being so great as to leave little room for all the other requirements.

Mr. Reed said that the *Novgorod* made a speed of 8½ knots on the measured mile; that she had steamed a considerable distance at 7½ knots, and when he made a trip in her the speed averaged 6½ knots, this last probably being the real speed when steaming in ordinary weather for a period of twenty-four hours or more.

The table on this page gives the principal details of the *Novgorod* and the *Admiral Popoff*.

THE OLDEST RAILWAY IN THE WORLD

FROM SWANSEA TO MUMBLES, IN WALES

By Thomas Rees

THE CAR USED IN 1805

MUMBLES, a charming little watering-place on the Gower coast in Wales, is generally noted for two things. Its parish churchyard is the resting place of Thomas Bowdler, who "revised" Shakespeare to make the Bard of Avon's work palatable to Mrs. Grundy, and its lighthouse island was the scene of the heroic incident depicted in Clement Scott's popular poem, "The Women of Mumbles Head." It has, however, a third claim to fame, and one which, in these days of rapid transit and feverish commercial activity, may be regarded as the most substantial. It is the objective of the Swansea & Mumbles Railway,—the first line of railway authorised by Parliament, the Act sanctioning its construction having been passed a hundred years ago last month.

The most recently published returns show that last year there were 22,152 miles of railway open in Great Britain, and that the 351 companies owning them carried the unimaginable number of 1,188,219,269 passengers. When one tries to grasp the stupendous character of those figures and realises how utterly helpless we would be rendered by even a temporary stoppage of railway communication, it is a little difficult to believe that a hundred years ago the British House of Commons was only commencing to deal with those great problems of transit which now recur with sessional regularity. It is true that in 1776 a tramline had been constructed for the conveyance of minerals at Colebrook,—a line which the colliers, out of an aversion to new-fangled ideas, destroyed, —and three years earlier than 1804 application had been made to the Legislature for powers for a line along the banks of the Thames in Surrey; but the Swansea to Mumbles railway is the first line now in existence constructed under Parliamentary authority.

It is unique in other respects also, since its working illustrates the continuously progressive development in the means of traction. Its cars have been carried from point to point by sails filled by the westerly breezes of Swansea Bay; horses have drawn its carriages; steam has been employed, and to-day it is the only railway in Great Britain served by self-contained accumulator cars.

No one now sings of "our old nobility" as did the Duke of Rutland in his salad days, but even where it is most vigorously contended that the aristocracy have taken much, it must be conceded that they have given a little, too. It was the Marquis of Worcester's observations in the Tower of London that first laid the foundations of the great engineering industry of Great Britain. It fell to a descendant of the Marquis to pioneer that work of railway construction which was the natural complement of the invention of the steam engine. The seventh Duke of Beaufort was the

"OLD SWANSEA,"—THE "TRAIN" OF 1865

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A COMBINATION STORAGE BATTERY CAR OF THE PRESENT TIME ON THE MUMBLES RAILWAY

possessor of much mineral wealth lying to the west of Swansea. To bring it profitably to the harbour he must employ cheap labour or secure cheap transit He chose the latter, banding himself with fourteen others for the construction of a railway.

It was a modest request they made to Parliament. The line they wanted to construct just outside the limit "where the garrulous sea sits talking to the shore" was only five miles long, and the capital of the partners was only £8000, with power to raise on mortgage half that sum again; but when the times and manners are taken into proper account, their enterprise deserves to be placed on a par with much that is claiming admiration at the present day. They were men fighting to keep abreast of the time. They "dipped into the future far as human eye could see," and their sagacity found its reward, as may be gathered from the fact that the line yields its owners a comfortable and well-assured income of 8 per cent.

The line was primarily intended for mineral traffic, and it served its purpose so well that the mines it was intended to develop have long since been worked out, and the railway is now, before all else, a pleasure railway, deriving the greatest portion of its revenue from holiday traffic. A guide book published in 1826 says:—

"There is a carriage somewhat resembling the long coaches near the Metropolis, which twice a day goes and returns from Swansea and the Mumbles, carrying sixteen passengers."

That is the carriage pictured in the little illustration at the beginning of this article, and it forms a marked and striking contrast to the well-equipped car shown in the lower illustration on page 331, which, running hourly, carries in the summer as many as 1800 passengers, whose needs are further catered for by intermediate trains of the most modern electric cars in Great Britain.

Just as the line illustrates the great advance in railway equipment, so it shows the progress of managerial ideas or the cultivation of traffic. The recent holidays have witnessed unexampled efforts on the part of the great railway companies to induce passengers to leave the towns and get into the country, or *vice versa*. It was not always thus on the Mumbles line, at all events. They had no great love for the tripper. They carried their preference for his room over his company to such an extent that on Good Friday and Whit. Monday,—the two chief holidays of the year,—they actually increased the fare from a shilling to half-a-crown, and troubled not a bit because the excursionists growled and declared they would never come again. They deal very differently with him nowadays. The motto here, as elsewhere, is to "get traffic," and that solicitude for the pleasure-seeker is appreciated may be gauged by the circumstance that last year the company carried nearly 2,000,000 passengers, and that without a single accident.

Current Topics

It has frequently happened in the past that when one cable in a system of underground conduits has burned out, the fire has spread to many of the other lead-covered cables in the manhole, the heat and flame from the burning insulation and molten lead of the first cable to give way melting the lead of the adjoining cables, the insulation of which added fuel to the flames. On several occasions in the city of New York more than thirty single cables in a manhole have been destroyed and the service has been crippled for hours by the burning-out of one cable. To avoid this wholesale damage to the cables, as well as to avoid the loss of revenue due to delays to service, it was proposed by William Maver, Jr., eight or ten years ago, to the electric lighting and power interests, that the important cables in the manholes be wrapped with asbestos paper, or that they be covered where they pass through the manholes, with a metal that would resist the flames; but the cost of such protection was thought to be prohibitive at that time. Of recent years, however, with the advent of much larger cables, operating at much higher pressures than formerly was the case, these and other forms of protection to the cables against fire in the conduits are now being quite generally adopted. Where asbestos paper is used, it is wrapped around the cables in strips in the manholes and for a short distance into the ducts, strips of brass, laid spirally, binding the asbestos to the cables. In other cases the asbestos is further protected by a sheet iron sleeve. Still another plan is to protect the cables by putting over them vitrified clay piping in half sections, suitably supported. By such precautions a burn-out in one cable is confined to that cable. In the new power house of the Interborough Rapid Transit Company in the city of New York the cables are not as hitherto suspended along the walls or ceiling, but for similar reasons to those just mentioned, multiple ducts are built along the inside walls of the power house, into which ducts the large power cables are drawn.

It is generally believed that boiler explosions of a destructive character never occur except in connection with high-pressure boilers, used for power purposes. In point of fact, however, as told in a recent issue of *The Locomotive*, heating boilers in which the pressure is not intended to exceed four or five pounds per square inch frequently explode in such a manner as to cause a destruction of property, which appears to those who have not computed the enormous heat-energy stored up in hot water to be entirely disproportionate to the cause that gives rise to it. Even kitchen hot-water boilers explode in this manner from time to time, with disastrous consequences. As corrobora-

tory evidence, *The Locomotive* prints several illustrations relating to an explosion which occurred a short time ago in a prominent club house. These serve admirably to establish the necessity of attending most carefully to the conditions under which the simplest and apparently most innocent types of boiler are operated. The boiler which exploded in this case was situated in the kitchen, in the basement of the building. There was no fire under it, the water that it contained being heated in the usual manner by a water-front in the kitchen range. It consisted of an ordinary upright cylindrical copper tank, and differed from the tanks that are found in nearly every household solely by reason of its greater size, its cubical capacity being about 300 gallons. On the evening of the explosion the kitchen was unusually busy, and the fires in the range were correspondingly active. At about ten o'clock, and with no previous warning, the boiler suddenly gave way, blowing out part of the front of the building and generally wrecking the interior. The entire building was shaken, the floors being apparently lifted bodily to a greater or lesser extent, so that every person who was in the same general part of the building as the boiler experienced a violent vertical shock.

The boiler was not supposed to be subjected to any pressure whatsoever, save that prevailing at all times in the city water mains, namely, about sixty-five pounds per square inch. There could be no doubt that the boiler was perfectly safe at this pressure; hence it became evident that some cause was operative which permitted the actual pressure to exceed the normal pressure in the city mains by a very substantial amount. Investigation revealed the following facts:—Upon the supply pipe which entered the club house from the street there was a water-meter, and on several occasions the fires in the range had been pushed to the point of generating steam in the water-front, so that some of the water in the boiler had been forced back towards the street mains. The water thus caused to "back up" being hot, did more or less damage to the meter, through which it had to pass in order to leave the boiler, and after this had happened several times, orders were given that a check valve should be placed in the supply pipe to prevent further damage of this sort. Now there should never be a check valve in the pipe between a kitchen boiler and the water main which supplies it, for when the fires are run hard enough to generate steam in the water-front it is evident that one of two things must happen. Either a portion of the water must escape from the tank and piping in some manner, or the pressure in the system will rise to an intensity which may be great enough to disrupt the boiler or the piping. If the boiler is always in free communication with the city main, it is plain that the pressure can never exceed that of the city supply; but when there is a check valve in the supply pipe it is not possible for the boiler to relieve itself by discharging a portion of its contents back through that pipe, for the first tendency towards such an efflux causes the check valve to close, and thereafter the boiler must be regarded as a sealed vessel, the pressure in which may rise to a point which is determined only by the strength of the boiler and by the intensity of the fire in the range. The man who ordered the check value put in was thinking solely of the damage that the hot water might do to the meter, and did not give proper consideration to the consequences of such a valve, so far as the pressure within the boiler is concerned.

Of course, an accident of this kind could be prevented by providing the hot-water boiler with a suitable safety valve, and if such a valve were placed upon it the objection to the check valve would be far less serious. Safety valves are seldom placed upon kitchen boilers in the United States, however, though in Great Britain they are quite common, "dead weight" valves having the preference for this purpose over those of

other types, on account of their simplicity and reliability. It does not appear that any safety valve had been provided in the case of the boiler here mentioned, and even if there was such a valve, it certainly was not operative. One need not regard a kitchen boiler as dangerous, if it be provided with a check valve in the supply pipe, and also with a safety valve of some approved type, suitably located and properly cared for. It should be remembered, however, that safety valves are likely to corrode and stick; and if they leak a little, they may become such a source of annoyance as to tempt the queen of the kitchen (or the chef, it may be) to deposit a few bricks or flatirons, or other portable miscellany, upon them, to keep them tight. On the whole, therefore, the omission of the check valve altogether is to be advised; and if there is any trouble, either to the meter or to any other appliance, from the "backing up" of hot water towards the city main, a second tank of suitable capacity should be placed upon the supply pipe, between the kitchen boiler and the meter. Such a tank can be easily arranged so as to receive the hot water from the boiler in its upper part, while discharging an equal quantity of cold water from a connection at the bottom, back through the meter.

These remarks are not to be construed as being in opposition to the use of a safety valve upon a kitchen boiler, for such a safeguard is a most excellent thing; but it is bad practice to put in a check valve, even when a safety valve is present; for by doing so we are forced to rely altogether upon the continued good condition of the safety valve, and experience indicates that the mechanical instincts and training of kitchen help in general cannot be relied upon to see that a safety valve is always in good order. As an additional safeguard, the safety valve is a good thing, and it is especially to be recommended in the colder latitudes, where the supply pipe may freeze in the winter, and hence prevent the boiler from relieving itself by the "backing out" process. It is practically a necessity to have a stop valve somewhere upon the supply pipe of a kitchen boiler; but we always counsel placing this in such a position that it cannot be confused with any other valve, and hence cannot be closed through mistake. It is a good plan to secure this valve, when open, with a wire, for this lessens the likelihood of its being closed accidentally, and it is no trouble to break the wire which fastens it in case of emergency.

The extent to which natural gas is used in America is well illustrated in the latest volume of "Mineral Resources," published by the United States Geological Survey. Iron mills, steel works, glass works, and various other establishments to the total number of 8103 made use of its energies in 1902. The number of natural gas companies that supplied the 509,695 home consumers and the 8103 establishments in 1902 was 2147, which represented a gain of 602 companies over the enrollment of 1901. One of the most effective uses to which natural gas has been put is as motive power for engines. The natural-gas engine came into favour about ten years ago, when its use was first employed in pumping wells. Afterward, in sizes ranging from 5 to 500 horse-power, it was extensively introduced into manufacturing plants, where it successfully demonstrated its economy and reliability, and in many cases replaced the steam engines and boilers.

It is worth noting that in the recently completed report of the steam turbine committee, which was appointed some time ago by the Cunard Line to report upon the expediency of using steam turbines for the propulsion of new large vessels to be built for the company, little saving of weight or area occupied is claimed for the turbine equipment, as compared with the more time-honoured kind of engines. The machinery of the new ships, to maintain under all weather

conditions a mean of 65,000 indicated horse-power, will be only 300 tons lighter than with reciprocating engines; but the committee counsels the Cunard Company not to rely on this saving to the extent of adding such 300 tons to cargo or other accommodation. It should be held in reserve in design for machinery. The one important disadvantage dwelt upon is the lack of economy at low speeds; but it is pointed out that, as the new Cunarders, unlike warships, will always run at a uniform speed of 24½ knots, this should be considered a minimum in proportioning the turbines, so that at that speed the greatest power will be insured, and then the coal and steam consumption should be superior to the reciprocating engines.

TESTS of steam turbines on land, especially where superheated steam was used, showed a marked superiority in economy, as compared with results in marine practice; but the only data possible in connection with marine turbines were deduced from trials with the English Channel turbine-propelled vessels. At full speed these showed a better economy by 2 per cent. than where reciprocating engines were used. The committee, however, is careful to point out that this result cannot be accepted as final, as there were several factors influencing efficiency which could not be eliminated. These vary results greatly. The form of the stern of the ship and the distance of the propellers from the hull are also disturbing factors, and importance is attached to these, although they were not within the scope of the investigations of the committee. Further tests are to be made with models at the government tanks; but, apart from this one point, all the general questions have been definitely settled. Economy, too, will result from the use of the turbine by the reduction of the staff in the engine room and by the absence of lubricating oil in the exhaust steam.

THE committee has recommended four shafts, not only because the four screws will give a higher efficiency, but because it was imprudent to divide the power through a less number of shafts. The committee considered the power necessary to give the sea speed of 24½ knots with various forms of hull, and although 24½ knots can be realised at sea under normal weather conditions, it is necessary to have a considerable margin of power to insure that this rate will be maintained under adverse conditions; and for this reason 25 knots will be attained on an extended trial trip. Consequently, with three shafts, the power transmitted through each would require to have been about 25,000 indicated horse-power, whereas with four shafts it will not much exceed 18,000 indicated horse-power, which has already been adopted in one or two cases. There was also the question of the size of the turbine and the advantage of limiting the number of revolutions per minute of the screw propellers. Large diameter improves the sea manœuvering quality, and thus the committee started with the proposition that the revolutions should be limited to 140 per minute. This is considerably more than with reciprocating engines, but it compares with the 300 to 500 revolutions at which smaller turbine-driven vessels are now run. The design of turbine will differ slightly from that in other ships, and here it may be stated that the committee did not consider other systems than the Parsons, since there was no sea experience with others; hence that turbine will be used. Although the rate of revolution is commendably low, the turbines will have to be of great diameter to give the power, and the peripheral speed will consequently be very high, but no greater than with existing turbines.

THE greater diameter of the turbines affects their arrangement in the machinery room of the ship. As recommended by the committee, there will be one go-ahead turbine on each of the four shafts, which will be almost equidistant from each other. The high-pressure turbines will be mounted on two outside shafts,

an arrangement which enables the shafts to be far from the centre of the ship without interfering with the lines of the hull. These shafts will have the propellers at a considerable distance from the stern of the ship, so that there will be the minimum of disturbance to the flow of water to the two inside propellers, which will be placed right aft in the usual way. On each of the two inside shafts there will be two turbines. One set of these will be the two low-pressure turbines for driving the ship ahead. The other two are for astern motion. It will be noted that the power for ahead motion is in two steam units, each with one high and one low-pressure turbine, giving the best expansion of steam; but should there be any breakdown of one shaft, turbine or propeller, the three remaining shafts may be run, and thus only one-fourth of the power will be unavailable. Since the turbine can be overloaded to a very much greater extent than the reciprocating engines, it will be possible to reduce this proportion of lost power very considerably, so that with a fractured shaft the sea speed may not fall short of the normal rate by more than a mile or a mile and a half per hour. Regularity is thus further insured. Another advantage of the four screws and of the two central shafts being fitted with astern driving turbines is that the power for driving astern will be equal to about one-half the forward motion power distributed through two shafts. And here, again, the possibility of an overloading of the turbines will add to the manœuvering qualities, and reduce the time and distance required for bringing the ship to a state of rest when running at full speed ahead.

One of the most important problems at present demanding consideration in connection with blast furnace practice is the purification of the gas coming from the furnaces. It is a fact, pointed out by Mr. E. A. Uehling recently before the American Institute of Mining Engineers, that with but few exceptions, the gas of the modern blast furnace carries more dirt into the stoves and under the boilers to-day than was the case a quarter of a century ago. It is true the dust-catchers have been increased in size and dust-pockets have been multiplied, but the subject has not received the attention that its importance demands. It has been entirely overlooked that, with clean gas, the heating surface of every hot-blast stove could be doubled and the steaming capacity of every boiler increased at least from 30 to 50 per cent., and that the capital now being invested in additional stoves and more boilers, which the heavy repairs and frequent stoppages, caused by the dirty gas, make necessary, would in most cases be more than sufficient to install an efficient washing plant. There is no improvement that could be suggested in connection with the modern blast furnace that would yield a greater return from the investment than an efficient gas-washing plant, except the blast furnace gas engine, and this latter must necessarily be served with clean gas.

The case of electric heating, especially for domestic service, was presented at a recent meeting of the National Electric Light Association of America by Mr. James I. Ayer in a way well designed to make the householder appreciate its many good points. There are, as Mr. Ayer told, many convenient electric heaters of small current consumption, effective in supplying wants that gas cannot meet. Electric curling-iron heaters, for example, use 50 watts, and are rarely in service more than a few minutes at a time. The electric heating pad, or substitute for a hot water bottle, is an invaluable device when required, and uses but 50 watts. Electric flatirons are made for sewing-room use, of 200 or 300 watt capacity, and though frequently in commission, the period of operation is short, so that the monthly consumption of current is small. They save many trips to the kitchen for a hot iron to press a seam or a bit of lace. An electric tea-kettle

or stove using 200 watts, or a small cup with heater, will produce afternoon tea for two, heat milk night or day, heat shaving water, and is of much value in the sick room. With two small stoves, a breakfast of eggs, toast and coffee can be prepared on the dining table while you wait, and you will not wait as long as usual. A chafing dish, of course, is more useful for general cooking in the dining-room, and until one has "lived with an electric chafing dish," he does not know its possibilities. These require 200 or 500 watts, according to the size, and are cheaper to operate at lighting rates than the alcohol kind. An automatic coffee urn for the breakfast table does its work perfectly in from ten to twenty minutes, using 200 to 400 watts, according to size. For the man of the house, inclined to tinker, an electric soldering iron, using from 100 to 200 watts, is useful, as well as a small glue pot. All of the above-mentioned articles are usually supplied with lamp socket plugs, and are sold ready to connect. Nothing in the way of special work is required to put them into service; their operation is quickly understood, and most are of such low price as to be easy to introduce. Such articles are the best possible advocates for the more extended use of the electric service in the household, and will do much to make a satisfied customer. The fact that, except the heating-pad, none of the articles are at work for more than from ten to thirty minutes at a time, makes the aggregate for the month but a small addition to the total bill, yet a material gain to the station, for it is added output on existing service wires, and the articles serve as missionaries for the central electric supply station.

As to the cost of electric domestic heating and cooking, Mr. Ayer makes the point that while low rates for current will be necessary to popularise the electric method generally, it has a wide field at higher cost than its competitor, gas, and for the same reasons that gas has had such generous recognition, although it costs more than coal. Electric lighting, too, it may be called to mind, costs more than gas directly; but its many advantages, such as cleanliness, convenience and safety, are gains that are now appreciated to have a cash value. In houses where the work is in the hands of the ignorant "help," there is not a good field to-day for electric cooking; but in the home where the mistress is the cook, entirely, or in part, and in small houses in suburban towns and the smaller cities, the field is wider. The freedom from heat, offensive products of combustion, and leaky valves; the inevitable soot, dirt, and chance explosions incident to gas, and the absence of all cooking devices between periods of use, owing to the portability of electric heaters, are tangible advantages in addition to the more perfect results obtained. In thousands of homes gas is used as an auxiliary to the coal range for some of the lighter meals at all seasons, and for much of the general cooking in summer, when the range is not required to be put in commission for other purposes. For all such purposes, Mr. Ayer concludes, electric cooking is not only possible, but more attractive and satisfactory, all things considered, than any other method.

One feature of the problem of employment and wages which does not seem to have received a fair degree of prominence is that when work is slack employment decreases and wages fall,—a double loss to the wage-earner; and the dearth of employment is far more serious than the lower wages. In this respect census and other reports dealing with the rise and fall of wages have been most misleading. The question is only very slightly whether the average wages per year of those actually employed are higher or lower, but whether more or less men are employed in their trades at reasonable wages. Mr. Harrington Emerson recently suggested, therefore, in a paper read before the American Society of Mechanical Engineers, that government influence might be made to

act as a fly-wheel for the energy of production. He proposes that when labour is scarce and materials high, governments, national and municipal, should carefully abstain from undertaking great works of creation or improvement; but when labour is plentiful and materials low in price governments should carry out plans held in reserve for just such conditions. There is, he believes, no other means at once so powerful and economical to minimise the ups and downs of both labour and capital. It is in the power of government to establish a minimum wage (as well as a minimum price for great staples) at which it is always ready to undertake great elementary works of public utility,—dredging canals, for instance, or opening roads. In some such manner as this Mr. Emerson would have the State take a hand in helping to fix the minimum wage. On the other hand, every wage-earner should keep constantly in view the possibility of obtaining a much higher rate than the average,—a rate wholly due to his own reputation and accomplishment; a rate far above the minimum offered by government, and also much above the mean due him as an able-bodied, skilled, trustworthy craftsman. This extra rate must always be based on the fact that he is more skilful or valuable than the average. He may be more skilful to-day, just as a prize-fighter may be the champion of the world to-day; but next year both may be no more than mediocre. He must constantly excel if he would constantly command a professional price.

THE Great Western Railway Company recently put down in their erecting shop at Swindon a locomotive testing plant, of which Mr. G. J. Churchward, the company's locomotive superintendent, gave an account in a paper read before the Institution of Mechanical Engineers. The installation, as described by him, consists of a bed made of cast iron, bolted on a concrete foundation, with timber baulks interposed for the lessening of vibration. On this bed five pairs of bearings are arranged to slide longitudinally, so that they may be adjusted for any centres of wheels that are to be put upon the plant. In these bearings axles are carried having wheels fitted with steel tires, on which the locomotive runs. These axles are also fitted with drums on which band-brakes act for absorbing wholly or in part the power developed by the engine. Outside these band-brakes pulleys having an 18 inch face are provided at each end of the axle for driving link-belts by which it is intended to transmit the major portion of the power developed by the engine to air compressors, so that it may not be wasted. The hydraulic brakes will then absorb only just enough power to enable them to govern the speed of the engine. These brakes are actuated by a water supply from an independent pump, the outlet of this water supply being throttled either by a stop valve or by a throttle actuated by a centrifugal governor. This latter device enables the speed of the engine to be set at any required number of revolutions and kept constant. The carrying wheels are 4 feet 1½ inches diameter. The main bearings are 14 inches long by 9 inches diameter. The tire of the carrying wheels is turned to approximately the same section on the tread as the rails in use on the line.

THIS plant is intended not only for the purpose of scientific experiment, but also for doing away with the trial trips of new and repaired engines on the main line. It has, therefore, been necessary to make it rapidly adjustable to take engines having wheels of different centres. The main bed is provided with a rack, and each pair of bearings is provided with a cross shaft having a pinion at either end. These cross shafts are driven from a longitudinal shaft through suitable clutches, and the longitudinal shaft is operated by an electric motor and is capable of being reversed. The engine being run over the machine on an elevated frame which carries it on the flanges of its tires clear of the carrying

wheels, it is an easy matter to slide these carrying wheels with their bearings till they are vertically underneath the wheels of the engines to be tested. The frame is then lowered electrically and drops the engine into position on the carrying wheels.

When running engines on trial trips, it is essential that the bogie and trailing wheels of engines so fitted should be run as well as the driving wheels, in order that the axle boxes may take a good bearing, and be seen to be in a satisfactory condition before handing the engine over for traffic. To accomplish this, the carrying wheels are all coupled together by a suitable arrangement of belts and jockey pulleys. It, therefore, follows that, even when a locomotive having a single pair of driving wheels is run on the plant, all the carrying wheels are rotating, and, in turn, run the bogie and trailing wheels of the locomotive. The jockey pulleys are necessary to retain the proper tension on the belts when the bearings are moved longitudinally. Owing to the varying height of the footplates of different classes of engine, it has been found necessary to provide a firing stage which can be rapidly adjusted vertically. A large coal bunk and weighing machines are provided in connection with this stage. Two water tanks are mounted on the same platform for measuring the water used when running, these tanks being emptied alternately when a consumption test is being made. Under the platform a dynamometer enables the drawbar pull of the engine to be taken, and this, together with counters on the wheels, will enable the actual drawbar horse-power to be measured, and so compared with coal and water consumption for various classes of engines.

As engines of different lengths are to be tested, and of necessity have to be fixed at the trailing end to the dynamometer, it is necessary to have a sliding chimney for carrying off the steam and smoke from the engine when running. This has been provided in the form of a long box, having a steel plate running on rollers forming its lower surface, which plate carries a large bell-mouthed chimney. This box not only enables the chimney to slide longitudinally, but will also form a receptacle for ashes and any other matter ejected by the engine, which will be retained and can be examined both for quantity and quality. It is hoped that this plant will enable many questions of the relative economy of different classes of engines, either simple or compound, to be settled definitely. The questions of superheating and the efficiency of various forms of smoke-'ox arrangements might be investigated on it. The effect of various percentages of balancing can be investigated, and, in fact, any of the experiments which are at present being made on the road may be made on this plant, with the great advantage that any engine which may be selected can be placed in position ready for testing, and all connections made in a time probably not exceeding an hour.

The bronze entablatures for the new Williamsburg Bridge, connecting the boroughs of Manhattan and Brooklyn, in New York, recently cast in part by the W. H. Jackson Company, of New York, are interesting examples of the founder's art, in that never before have plates of such great size and thinness been cast in one piece with any fair degree of success. Each tablet is in three sections, 3/8 inch thick, the combined length being 52 feet 7 inches, and the width 4 feet 3 inches. The middle section, which alone has been cast, is 22 feet long and weighs over one ton. The weight of the entire tablet will be three tons. The composition of the bronze is in the proportion of 90 per cent. copper, 7½ per cent. zinc, and 2½ per cent. tin. At present market prices the cost per pound of the mixture would be about 15 cents, making the cost of the metal in each tablet $900. The contract price for the six tablets to be made

was in the neighbourhood of $7000. The pattern for the middle section was itself made in three sections to facilitate handling. In preparing the mould, the services of nine men were required for three days, and the weight of the sand-filled flask was about 12,000 pounds. The weight in itself was not a great hindrance, but the flask was 25 feet long and 5 feet wide, and proved rather a bulky object to manipulate. As the tablet was to be of such comparative thinness, very great precautions were necessarily taken to provide an even flow of metal to all parts of the mould. This feature in the case was by far the most important one, and contributed more than any other thing toward making the operation an important occasion in foundry work. The result was accomplished, however, by pouring the metal simultaneously at seven different holes, so that it first filled a trough running around the entire mould, and from this trough ran into the mould through 125 gates. Twelve hundred pounds of metal were poured into the trough from a ladle, held in position by a crane, and the remaining 1800 pounds were supplied from crucibles, each handled by five men. When the casting was taken from the sand it proved to be perfect in every detail. The melting of the bronze was also a radical departure from existing methods. Ingots of the desired composition were first made by the usual method of crucible melting. The composition was then placed with the fuel in a cupola and melted in the same manner as pig-iron, the molten bronze being drawn off at the bottom, as in cast iron work.

DURING a gale on a night in December, 1902, so many factory chimneys in Denmark were blown down that information was promptly invited respecting their construction and the damage sustained. The replies have been collected and reported upon by Mr. A. Ostenfeld, in *Ingenioren*, of Copenhagen, and are referred to in the latest volume of "Foreign Abstracts" of the Institution of Civil Engineers. Of six chimneys the particulars furnished were sufficiently complete for tabulating, and for calculating stability on the ordinary assumption of a static wind-pressure of 25 lbs. per square foot. According to calculation, a round chimney, 27 inches in diameter inside, 99 feet high, tapering 1 in 46, was far too weak; the height blown off from top downwards was 77 feet. Another round chimney, 40 inches in diameter inside, 118 feet high, tapering 1 in 18, would be considered so safe that its fall can seemingly be accounted for only by supposing the wind to have acted upon it in gusts happening to synchronise with its rocking; the height blown off was 30 feet. The four other chimneys were 18 inches square inside, from 72 to 87 feet high, tapering from 1 in 26½ to 1 in 38½; the height blown off was from 31 to 53 feet. Particulars are given of materials employed, with dates of erection and of latest working. In regard to the tensile strength of brickwork, this is so closely dependent upon the care exercised in building that it would be remarkable if the weakest joint were ever found to occur just where indicated by theory. Sometimes, too, a certain amount of shelter has been afforded to the bottom of a chimney by neighbouring buildings. The four following conclusions were drawn by Mr. Ostenfeld:—(1) No reliance should be placed upon empirical rules for the dimensions of a chimney, but the latter should always be calculated. (2) The wind pressure should be taken at 31 lbs. per square foot, acting for round chimneys upon two-thirds of their outside diameter. (3) Independently of the tensile strength, the neutral axis must not be further in from the windward side than the centre of the cross section. (4) For hard-burnt brick laid in cement-mortar the greatest crushing strain, when free from wind pressure, must not exceed 220 lbs. per square inch, unless the crushing strength has been proved by direct trial to be not less than 3670 pounds per square inch, in which case a higher crushing strain is permissible, up to not more than 367 lbs. per square inch.

In a short paper on "Direct-Metal and Cupola-Metal Castings," read recently before the American Institute of Mining Engineers, Thomas D. West said that a short time ago he had occasion to cast some iron plates an inch thick, with direct metal containing Si, 0.51; S, 0.045; Mn, 0.75; and P, 0.094 per cent. Much to his astonishment, there was no trouble in planing them, whereas if cupola metal of like composition had been used, the planing would have been a difficult operation. In view of the interest taken at the present time in the subject of using direct metal for foundry purposes, some of Mr. West's observations, while handling this metal in daily routine, may not be amiss. Mr. West told that he often noticed a greater fluidity or life in furnace metal when compared with the cupola product. Iron can be seen flowing down the furnace-runners from 50 to 100 feet before reaching the last pig in very satisfactory shape, while cupola metal might solidify before it had reached one-half the distance. Bessemer iron in a 30-ton ladle has been held for nearly an hour and a half during repairs to a crane, and after skimming off the coke dust, it had to be cooled off considerably before being cast. As a general thing it is known that the comparatively lower sulphur percentage and the higher temperature of direct metal over the same iron remelted in the cupola has much to do with its greater life, yet there are some problems connected with this phenomenon which would seem to call for further study. For instance, furnace metal containing more than 1 per cent. silicon holds carbon, which is separated as "kish." This separation does not take place to any great degree while the metal is very hot, but during its gradual cooling, at times, the kish is given off in such large quantities as to cover the ground for an area of from 20 to 30 feet around the ladle. Perhaps this throwing-out of the excess carbon makes the life of the metal shorter thereafter. It would be well to ascertain the carbon-content of a ladle of iron during the stages of the cooling process, and thus determine the effect of the carbon reduction more accurately. In making "direct metal" castings the separation of kish becomes a nuisance, although it is more generally confined to the higher silicon metals. The higher carbon undoubtedly has much to do with keeping metal with the lower quantities of silicon softer than if it were a cupola product of like composition excepting the total carbon-content.

To the late novelist, Lord Lytton, is attributed the forecast of the discovery of radium. In his marvelous imaginative work, "The Coming Race," in many respects the most remarkable of his writings, the novelist gave an account of the life led by a race of human beings far down in the bowels of the earth. The distinctive feature of the book, in fact, the pivot upon which the plot hinges, is the possession by those underground dwellers of a mysterious substance named "vril," and which, as described by Lytton, is, according to Hornblow, writing in *The Critic*, identical with radium. Hornblow summarises the similarities between radium and the substance hatched in the brain of the author as follows—"(1) Lytton says a small amount of vril could destroy a city as large as London, and that a child could destroy an army by merely pointing at it a staff charged with the substance; science assures us to-day that the power of radium is almost limitless, that two pounds of it could destroy three millions of people, and that one ounce would blow up a battleship. (2) Lytton's subterranean race lighted their streets with vril. Science tells us that radium gives out light and heat without waste or diminution. It is, therefore, only a question of quantity and proper adaptation when the world will use radium for lighting purposes. (3) This wonderful vril of the novelist could, he claimed, cure diseases. Indeed, the race depended wholly on it to restore or invigorate life. Experiments recently made with radium in hospitals demonstrate that it will cure certain forms of disease, such as lupus and other skin diseases. It is also be-

lieved that it will cure cancer; on the other hand, if applied differently, it will destroy life. Physicians declare that air rendered radioactive will cure consumption, and that water rendered radioactive will relieve stomach troubles." Could then, asks Hornblow, Lytton have been otherwise than inspired when he wrote half a century ago of vril—" It enables the physical organisation to re-establish the equilibrium of its natural powers and thereby to cure itself" ?

JOHN WILLIAM LIEB, JR.

The President Elect of the American Institute of Electrical Engineers

A BIOGRAPHICAL SKETCH

IT may generally be stated that at the present, more than at any previous period, the value of an engineering training is appreciated, and, therefore, it is natural to see men, who are essentially engineers by profession and whose immediate duties are, in the main, executive, in responsible charge of large enterprises.

John W. Lieb, Jr., was born in Newark, N. J., on February 12, 1860. He was graduated successively from the Newark Academy and the Stevens High School, securing at the latter institution the Stevens High School prize, only one of which is annually awarded to the most proficient scholar in the graduating class. He was graduated from the class of 1880 from the Stevens Institute of Technology, receiving the degree of mechanical engineer. He was the salutatorian of his class.

Mr. Lieb's success as an electrical engineer can be used as an illustration of the necessity of a thorough mechanical training as one of the fundamental elements of an engineering education.

After graduation Mr. Lieb entered the employ of the Brush Electric Company in Cleveland, Ohio, as a draughtsman. In 1881 he was employed by the Edison Electric Light Company in the city of New York as draughtsman, but zeal, ability, and ambition were recognised, and, in 1882, he was transferred to the testing and experimental department of the Edison Machine Works, on Goerck Street, in the city of New York. Edison at that time divided the several departments of the electrical industry into four interests:—First, the Edison Machine Works, where the designing and building of the generators were undertaken; second, the Edison underground tube; third, Bergman & Co., of New York, fixtures, etc.; fourth, lamps.

The names of Andrews, Bradley, Clarke, Hammer, Kreusi, Langton, Lange, Lieb, Lemp, Wheeler and Vail, were identified with these momentous times in the electrical art. It was at that time that Edison had completed his first successful dynamo, known as "Jumbo," which he sent to Paris for the exposition of 1881, where it was exhibited from October to the end of the exposition in November.

Up to the time Mr. Lieb became associated with the Edison Electric Light Company no unit larger than the "Z," 60-light dynamo had been operated. During the year 1881, however, an "L," 150-light and a "K," 250-light dynamo were ordered.

In 1882, in connection with the construction of the historic Pearl Street station in the city of New York, Mr. Lieb was assigned by Mr. Edison to assist in the test of the "Jumbo" dynamo, of a capacity of 1000 lights. In later years Edison said that he regarded the "Jumbo" dynamo as his greatest achievement. These experiments commenced on July 5, 1882,

when the first "Jumbo" was started, and continued until September 4, when, under the control of the Edison Electric Illuminating Company, of New York, regular service was inaugurated, making the Pearl Street station the first commercial station in the United States supplying current for lighting and power through an underground system. On that occasion Mr. Lieb was appointed first electrician.

Simultaneously, a syndicate was formed in Milan, Italy, for the purpose of supplying electric light and power, and Professor Colombo, as technical adviser, came to America to purchase a complete equipment of boilers, engines, dynamos and Edison underground system. Mr. Lieb was selected by him to supervise that undertaking. Work was commenced in Milan in October, 1882, and in June, 1883, regular service was instituted. Six Edison "Jumbo" dynamos direct-connected, to Armington & Sims engines, were installed.

After the successful starting of this plant Mr. Lieb remained ten years, serving successively as chief electrician, director of stations, and chief engineer in charge of the technical department of the company, afterwards engaging in manufacturing electrical apparatus, installing isolated plants, and constructing and operating lighting and power stations throughout Italy.

The Milan company was among the first, beginning, as they did, in 1886, to exploit not only a direct current, constant potential system, but also the alternating-current system. The Thomson-Houston arc system was also extensively used by them.

Just before Mr. Lieb's return to America he was engaged in the electric railway field in connection with the installation of the trolley system in the city of Milan. In 1894 Mr. Lieb returned to his former company in New York, the Edison Electric Illuminating Company, as assistant to the first vice-president. Since then he has been with these interests, and upon the consolidation of the several lighting companies of the city of New York under the corporate name of the New York Edison Company, he was appointed third vice-president, and later associate general manager, which position he now holds.

The Electric Testing Laboratories, of which Mr. Lieb is president, are an enterprise to which he has devoted much attention and thought, and has secured for them recognition as a commercial bureau of standards working in co-operation with the National Bureau o' Standards at Washington, D. C.

Mr. Lieb is the new president of the American Institute of Electrical Engineers, a member of the council of the American Society of Mechanical Engineers, a member of the American Society of Civil Engineers, past president of the Association of Edison Illuminating Companies and of the New York Electrical Society, and second vice-president of the National Electric Light Association. He is also a member of a number of hther national and foreign technical societies.

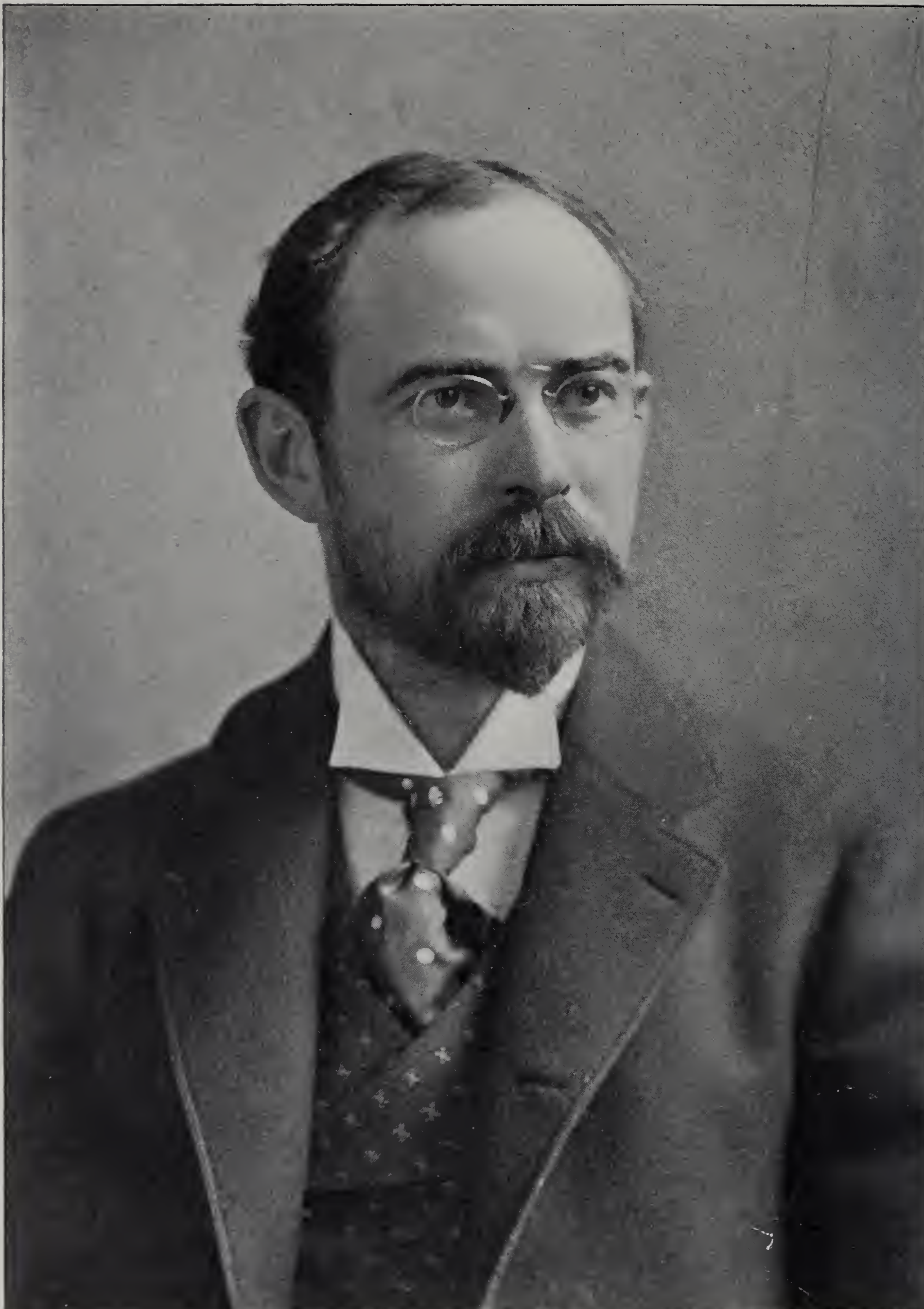

PHOTO BY FALK, NEW YORK

EDWIN WILBUR RICE, JR.

TECHNICAL DIRECTOR OF THE GENERAL ELECTRIC COMPANY, SCHENECTADY, N. Y.

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CASSIER'S MAGAZINE

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MINERAL SHIPMENTS AT BRITISH PORTS

By Brysson Cunningham, B. S., Assoc. M. Inst. C. E.

HAVING dealt in a previous article* with those appliances which are utilised for cargoes of a general character, it is now proposed to briefly review the various systems in vogue for the shipment of material of a more uniform nature, and, primarily, of minerals, such as coal and ore.

The annual mineral output of Great Britain is upwards of 290 million tons, of which about 227 million tons are coal and 13½ million tons iron ore. Of the coal, no less than 62 million tons are destined for shipment abroad, partly as bunker coal and partly as cargo, the quantity of the latter being 45 million tons. These figures are striking, and whatever may be their bearing upon the fiscal question, no doubt can exist as to the magnitude of their influence upon the problem of quayside shipment. No other country, probably, conducts so large a traffic in waterborne coal; certainly the United Kingdom has undisputed priority in regard to oversea shipments.

Germany, her nearest competitor, falls behind by at least 60 per cent. The exports of the United States (about 6 million tons), though rapidly increasing and at least double what they were four or five years ago, are still considerably less than the quantity, viz.:—7½ million tons,—sent by coasting steamers to London alone. It is interesting to note that the value of the coal exports of the United Kingdom reaches a sum of no less than £26,000,000,—equivalent to about 11s. 7d. per ton. Furthermore, every penny per ton spent in handling the coal amounts in the aggregate to £187,500.

This is entirely without reference to bunker coal generally and coastwise cargoes, statistics of which are not available. The effect of including them, it is needless to say, would be a considerable inflation of the foregoing figure, which, in itself, is amply sufficient to demonstrate the fundamental importance of economic manipulation in transport.

Next to coal, iron ore is the mineral which undergoes most extensive shipment. The quantity exported from the United Kingdom is not large, its value being only about £12,000; but the quantity imported has a value of nearly £5,000,000. Most of it comes from Spain, as also does the largest proportion of copper ore, the present total an-

* "Some Modern Quayside Cargo Appliances." May, 1904.

A GROUP OF COALING TIPS AT BARRY DOCKS

nual value of which as an import is £3,500,000.

The principal feature of general cargo was shown in the previous article to be its diversity, and the methods of dealing with it are, naturally, equally varied. On the other hand, the shipment of minerals manifestly lends itself to more uniform and systematic treatment; but even within a limited range of characteristics, there are marks of difference and distinctions to be carefully observed.

From the point of view of transport, for instance, coal, especially the South Wales product, is to be distinguished from other minerals by its extreme brittleness, and this quality involves increased care in handling, on account of the depreciation in value which is caused by breakage, and obviously still more by comminution. In fact, it is one of the most essential points to be considered in connection with shipping operations. Accordingly, almost every conceivable means has been or is being devised in order to reduce the amount of fall into the ship's hold, and thereby to lessen the effect of impact at the bottom.

The problem of coal shipment is rendered the more pressing at the present time by reason of certain changes which are manifesting themselves in the design of railway rolling stock for the conveyance of coal from the colliery to the quayside. Hitherto the net load has not generally exceeded 10 or 12 tons; but the colliery companies have recently placed large orders for waggons to carry 15 tons of coal, and in several instances, notably at Goole and Cardiff, arrangements are being made to deal with loads of 20 tons in the near future. Whether this increment will become general remains to be seen; but it apparently by no means marks a limit to possible extensions, for at Middlesboro the North-Eastern Railway Company are erecting appliances capable of dealing with waggons carrying no less than 40 tons of coal. Obviously, the saving in siding space and in tractive power by the adoption of capacious rolling stock is considerable, and this fact has long been recognised in the United States, where such waggons have been in use for some time. The practice of private ownership of waggons, however, militates against any rapid development of waggon accommodation in Great Britain, and it will probably be some years before waggons of 30 and 40 tons capacity become common.

The following table exhibits the principal dimensions and weights of rolling stock up to 20 tons capacity:—

LEADING DIMENSIONS OF TYPICAL BRITISH COAL WAGGONS

Net Capacity of Coal. Tons	Tare. Tons	Gross. Tons	Length Over Buffers. Feet	Wheelbase From. Ft.	Wheelbase To. Ft.	Wheelbase Average. Ft.
10	6.1	16.1	18	8	9	8.5
12	6.6	18.6	19.5	8	9	8.5
15	7.2	22.3	21	9.5	10.5	10
20	8.6	28.6	24.5	10	12	11

In the case of the all-steel bogie mineral waggon supplied to the Caledonian Railway by the Leeds Forge Company, the load is 30 tons, and the tare weight, 12 tons 16 cwts. The waggon is 37 feet 10 inches long over buffers and 53 feet long by 8 feet wide internally, with a capacity of 1206 cubic feet.

It would be no light matter to give an account of every variety of coaling appliance in vogue at the present day. The particular system desirable, or even available, at any port is governed in a great measure by the configuration of the site and the consequent disposition of the railway sidings which may be arranged in various ways so as to approach the quay either perpendicular to the coping line or parallel thereto. The practice on the North-East coast is not the same as that ruling in South Wales, and even within the bounds of the same locality there will often be a marked divergency of treatment.

The following are a few typical instances of the arrangements prevailing at leading ports:—At the coaling depots on the Tyne and the Wear the usual feature is a high-level approach, with discharge through the floor of the waggon into a spout, or shoot, inclined downwards towards the hatchway of the vessel. The same system of approach is adopted at certain of the tips at Barry

A SINGLE COALING TIP AT BARRY DOCK NO. 2

Docks, but in these cases the contents of the waggons are discharged by tilting the waggons. A third variation, to be found at Liverpool, Garston and elsewhere, is that of slinging the waggon by a crane bodily over the hatchway, generally through the medium of a cradle or platform. The coal is then allowed to fall, either through the floor of the waggon or out at one end. Lowering may also be effected with the assistance of a counterweight,—a practice which is not uncommon in the neighbourhood of Newcastle and Durham.

With the low-level approach a hoist becomes necessary, in order to raise the waggon above the level of the ship's bulwarks and coamings. After being emptied, the waggon is frequently withdrawn from the tip at some intermediate level, about 15 feet above the quay, so as to utilise the effect of an incline for the return journey. This is exemplified at Newport, Hull, Glasgow, Grangemouth, and other places. Sometimes the hoist is replaced by a crane, which lifts the waggon bodily from the quay, discharges it over the hatchway and re-

turns it to its former position. This method has been adopted at the Herculaneum Dock, Liverpool. Lastly, the waggon, instead of being lifted itself, may discharge its contents into a hopper placed in a pit in the quay. This is the Lewis-Hunter system, prevalent at Cardiff.

All these divergent methods have their special advantages and drawbacks. A high-level approach obviates direct lifting; but, on the other hand, it entails a track perpendicular to the general direction of the coping, or nearly so, forming in many cases an inconvenient intersection of the quay, in addition to causing the appropriation of much valuable space for inclines. The same drawback is apparent in the case of high-level return roads, though *per contra* there may be set down the advantages of gravity as a tractive agent. Discharge through shoots is a simple and effective expedient, involving a minimum of handling, and also affording facilities for screening; but the coal, in sliding through a distance of 25 or 30 feet to the mouth of the shoot, cannot fail to acquire some impetus which will augment the effect of its direct fall into the hold.

This may be remedied to a certain extent by the use of shutters and chains; but, in any case, there is inevitably a considerable amount of attrition and a liability to rush. An "anti-breakage" crane, of 2 to 5 or 6 tons capacity, is a common auxiliary of coaling tips, and the first few waggon loads are deposited by lowering the coal to the bottom of the hold in a box, or skip, until a coni-

COALING CRANES AT HERCULANEUM DOCK, LIVERPOOL

TRANSFERRING A WAGGON LOAD OF COAL IN BULK

cal heap is formed, of height sufficient to break the fall of the material which follows. This is a partial solution of the difficulty.

The slewing of a waggon over the hatchway minimises the disturbance and breakage; but the tare of the load is considerable, amounting to half the gross in many instances where a cradle is used. Thus, an appliance of 30 tons power is often able to deal with only 15-ton loads of coal. The Lewis-Hunter hoppers are lighter; accordingly, the proportion of useful load is greater, and discharge takes place within the hold instead of at the hatchway; but the method entails a twofold discharge of the coal, first into the hopper and then into the hold.

The last named system, which presents some features of interest, was introduced by the Cardiff Railway Company at the Roath Dock, Cardiff, in 1887. The cranes have a lifting power of 18 tons and an outreach of 40 foot radius, and they are movable along tracks at the quayside, recessed at intervals, within which are pits for the reception of the hoppers. These last are fitted with cone valves, and discharge can take place within 18 inches of the floor. The maximum fall from the waggon into the hoppers is 5 feet, but this applies, of course, to the first few lumps only. A single appliance has proved capable of loading 293 tons in one hour, and as many as four cranes may be employed simultaneously at the same vessel. The present equipment consists of eleven cranes, but the company intend to make considerable developments on the completion, in about eighteen months' time, of the new South Roath Dock, the south quay of which will be provided with cranes capable of dealing with gross loads of 30 tons.

The movable coaling cranes on the east quay of the Herculaneum Dock at Liverpool can deal with maximum loads of 25 tons at a radius of 41 feet 6 inches, allowing the suspending chain to hang plumb at a point 30 feet 3 inches beyond the coping line, and also to be luffed inwards to a minimum rake of 21 feet 6 inches. The total vertical range of lift is 50 feet, which can be performed at the rate of 90 feet per minute. The lowering speed is slightly greater. Slewing can be effected through a revolution and a quarter in 90 seconds.

The waggon, having been drawn on to the special cradle or platform, placed at any desired point upon the siding, is raised to a height sufficient to enable it to be swung directly over the place of discharge. The appliance is capable of locomotion along the track at the rate of 30 feet per minute. It is worked by hydraulic pressure of 780 lbs. per square inch, and the following are particulars of the working parts, which are carried at the rear of the framing:—Lifting ram, 25¼ inches diameter, stroke 12 feet 6 inches,—multiplying power 4 to 1; tipping rams, 22½ inches diameter by 1 foot 8 inches stroke, and 10 inches diameter by 8 feet 4 inches stroke,—multiplying power 6 to 1; luffing ram, 13 inches diameter, 7 feet 3 inches stroke. The cranes, of which there are two, were constructed by Messrs. Sir W. G. Armstrong, Whitworth & Co., Ltd., of Newcastle, and by the Hydraulic Engineering Company, of Chester. About 600,000 tons of coal are dealt with by them per annum. The maximum rate of shipment recorded for one crane is 354 tons, and the best average, 208 tons, per hour over a period of five hours.

In regard to these and similar statistics which follow, it is needful to bear in mind that the rate of shipment depends not on the capabilities of the crane, nor upon the facilities afforded for marshalling the waggons both before and after discharge, but largely upon such extraneous and uncontrollable circumstances as the trimming of coal in the hold and the manœuvering of vessels in and out of their berths. Cranes and tips are rarely, if ever, worked to their fullest possible extent, and any strictly numerical comparison of coaling performances would not only be invidious, but, in many cases, unjust.

The high-level coaling cranes at the Bramley-Moore Dock, at the same port, are of a fixed type, capable of dealing with loads up to 24 tons gross. They have a rake of 37 feet from centre of

A VIEW OF SOUTH QUAY, PRINCE'S DOCK, SHOWING 25-TON HYDRAULIC COALING HOIST AND INCLINE FOR TAKING AWAY EMPTY WAGGONS, CONNECTED BY VIADUCT

ANOTHER VIEW, SHOWING THE COAL WAGGON INCLINE AT THE LEFT. SEE PAGE 357

CRANES ON THE QUAY AT CARDIFF

pivot to plumb line of suspending chain, and a height of 36 feet 6 inches from rail-level to pin of jib pulley. There are three lifting cylinders of 15⅜ inches diameter and 14 feet 6 inches stroke, two slewing cylinders of 11½ inches diameter and 9 feet 9 inches stroke, one tipping cylinder of 9 inches diameter and 9 feet 8 inches stroke, and one return cylinder of 5½ inches diameter and 14 feet 6 inches stroke. All the cylinders for each crane are situated in a pit or chamber at quay level. The greatest performance of a single crane is registered at 306 tons in one hour, with an average of 234 tons per hour for four hours, and the nine cranes deal with a million tons of coal per annum.

The port of Barry, like most of the South Wales ports, is essentially a coal-

ing depot. Its coal export trade for 1903 amounted to nearly 9 million tons, and at its two docks there are no less than thirty-eight tips for dealing with it, of which twelve are low-level and twenty-six high-level. The tips have lifts ranging from 37 to 45 feet, and are capable of lifting 20 tons each.

In the high-level tip the rails of the viaduct are 25 feet 9 inches above the quay and 36 feet 9 inches above the average water surface of the docks. The approach sidings for full waggons have a gradient of 1 in 233, while the empty waggons are run off at a gradient of 1 in 70 to a length of road, from which they are collected and returned to the collieries. The tips are worked by hydraulic power, with the difference that at No. 1 dock the rams are direct-acting, the cylinders being sunk in a chamber below quay-level, while at No. 2 dock they are placed on the side of the tip, and lifting is performed by chains over pulleys at the summit of the tip. Anti-breakage cranes are provided in all cases.

The illustration on page 348 shows a group of two fixed and three movable tips arranged specially to meet the requirements of very large steamers. The movable tips are adaptable to any hatchway position. It seldom occurs, however, that more than three of these tips can be worked simultaneously into one vessel. The greatest quantity put on board a steamer by two tips, conjointly, has been at the rate of 775 tons per hour. A single tip has worked at the rate of 462 tons per hour for four and one-half hours, and, on another occasion, at the rate of 458 tons per hour for four and one-quarter hours; but both the vessels filled were what is known as "self-trimming" steamers, *i. e.*, they had enormous hatchway area.

A large coal hoist and tip, capable of dealing with a load of 25 tons, has recently been erected on the south quay of Prince's Dock, at Glasgow. The extreme range of lift is 50 feet. Waggons are ranged upon a cradle for hoisting, and after discharge they are returned along a viaduct with an incline downwards from a point 20 feet above quay-level. The hoist has proved capable of discharging forty to forty-five waggons per hour. Immediately adjacent is a movable 25-ton steam crane, capable of coaling an independent ship, or of acting in conjunction with the hoist.

A fixed coal hoist capable of lifting 32 tons constitutes one of four appliances,—two fixed and two movable,—now in course of installation at the Caledonian Railway Company's new dock extension at Grangemouth, the contract being entrusted to Messrs. Sir W. G. Armstrong, Whitworth & Co., Ltd. The height of lift is 50 feet, and waggons, after being run on to a cradle and discharged, will be returned, as in the previous instance, by a high-level run-away road. The dimensions of the working apparatus, which is fixed to the side of the framing, are as follows:—Large lifting ram, 1 foot 8⅝ inches diameter; small lifting ram, 6 inches diameter; constant pressure ram, 9 5-16 inches diameter; all 25 feet 4½ inches stroke; tipping ram, 1⅜ inches diameter, 10 feet 4 inches stroke. The multiplying power in all cases is 2 to 1.

Hitherto we have treated of appliances, the use of which is confined to the shipment of coal. There are two other systems of manipulation which may be considered generally applicable to all kinds of mineral substances, whether of the nature of fuel or ore. These are, firstly, the transporter, with its vertical tower and horizontal track, along which the material is conveyed in skips, or buckets, and discharged either by overturning or by flaps in the bottom; and, secondly, the crane, with grab bucket worked automatically. Both these appliances,—the transporter and the crane,—have been treated in regard to their general structural features in the previous article, and it is unnecessary to make any further reference thereto.

The transporter is largely adopted for coaling vessels from lighters and barges, in which event it may in itself be an independent floating structure, or, as has been successfully done in the case of warships at sea, the horizontal track may be fixed to the mast of the

COALING CRANES AT BRAMLY-MOORE DOCK, LIVERPOOL

ORE AND COAL STEAMERS AT ROATH DOCK, CARDIFF

vessel. The appliance is also in extensive use in connection with the import trade. Single transporter loads are, of course, much lighter than those dealt with by the structures previously described, but this is largely compensated for by greatly increased rapidity in action. One complete cycle of operations, lowering the bucket, filling it, traversing and discharging, can be performed in as little as fifteen seconds. An average duty would range from 50 to 80 tons per hour for plant of the usual capacity,—say, for loads of 25 to 35 cwts.

As regards the quayside manipulation of ore, little remains to be said. The quantity shipped from Great Britain is insignificant in comparison with the export of coal. And though, on the other hand, the import trade is far from inconsiderable, still it will be admitted that in both cases at most ports the quantity is hardly sufficient to justify the introduction of large, special and expensive installations for the purpose of dealing with it.

In the majority of instances the crane and the transporter, or conveyor, are quite capable of effectively loading and unloading such material, and they are, accordingly, the principal agencies employed. Copper ore is often conveyed in bags; but whether in this form, or, as with other materials, in bulk, the material is readily dealt with by means of skips.

The bucket conveyor, in the form of an endless train of buckets or troughs, working either horizontally, vertically, or along an inclined plane, has been introduced of late years, and its operations have been attended with a promising degree of success. When used for shipment, it is arranged in conjunction with a floating barge, along the longitudinal axis of which is arranged a central alleyway, wherein the bucket travels, with an upward prolongation at the bow, supported by a derrick. The summit of the incline is adjustable to a shoot fixed at the level of the steamer's deck. The principle has also been adopted for the shipment of bunker coal

from barges, but its introduction into the port of London in 1897 met with considerable opposition from the men engaged in the coaling trade, so that the method had to be abandoned.

While local conditions and practice must undoubtedly be the predominant features in determining the type of machine most suitable for a particular port, there are nevertheless certain essential considerations equally applicable to all cases by which the efficiency of any appliance can be subjected to a general standard of reference. These considerations may be summed up as maximum rapidity of action; minimum expenditure of energy; and almost inevitably economy in working cost. To these must be added, as an essential in the case of coaling appliances, the safeguarding of the material, as far as possible, from fracture.

THE STUDY OF SCIENCE

ITS NEED IN MODERN EDUCATION

By John Brisben Walker, Editor of "The Cosmopolitan Magazine"

In the August number of *The Cosmopolitan Magazine*, under the head "What Is Education? The Studies Most Important for the Modern Man," Mr. Walker forcibly illustrates the need of science study in modern university education. Through his kind co-operation, it was made possible to print the article simultaneously in this issue.—THE EDITOR.

THE complaint is made that the modern university has no disinterested body to determine what education should be. That all-important subject is decided by professors, whose personal interest would be at stake if any radical changes were to be made in the accepted curriculum. The result is very well illustrated by the recent action at Princeton.

Men who have been laboriously trained to teach Latin and Greek, would show themselves phenomenally disinterested should they suddenly exclaim:—

"Yes, we will step down and out, and yield our places to new men who can teach science, giving the new studies the most important place in our university."

How could these be expected to fully recognise science when they themselves, these Greek and Latin scholars, know so little of science? Therefore, the action of the professors at Princeton, as reported in the press, withdrawing the elective privilege from the students and re-establishing Latin and Greek in a position almost as important as they occupied two hundred years ago, is not very surprising.

But it is worth while, in view of this fact, to examine:—

I. What are the classes of men who must study science if they would keep their positions in the world of to-day.

II. Just what need the men in each of these classes have for science, and why.

A brief list of those who must have a good knowledge of science, if they are to hold their own amidst modern progress, would include the following:—

I. The Engineer.
II. The Clergyman.
III. The Lawyer.
IV. The Manufacturer.
V. The Merchant.
VI. The General Business Man.
VII. The Farmer.
VIII. The Doctor.
IX. The Artist.
X. The Literary Man.

I. The Engineer:—It will scarcely be necessary to discuss the equipment of the engineer. There are those who might argue the advantage of his being equipped with such knowledge as that engineer had who recently headed a paper on bridge-making, "De Ponti-

bus.'' When some one expressed surprise that a scientific treatise should thus be entitled, he made reply:—

"Well, the fact is, I spent six years studying Latin and Greek, and I have been waiting thirty years for a chance to use that knowledge; and this seemed to be my only opportunity. When I remember what I might have done with those six years devoted to science, you will appreciate my impatience, and make excuses for 'De Pontibus.'"

II. The Clergyman:—There has been much discussion of late as to why young men do not attend church. Does it occur to any one to question the ability of the preacher educated in Latin and Greek, perhaps to the exclusion of modern science, to entertain the mind of the bright young man of the business world, who reads the reviews, subscribes, perhaps, to two or three scientific publications, who is up in the latest discoveries, has read of the work in the ruins of Mesopotamia, who knows his geology, and has, perhaps, a fair knowledge of what science teaches of the universe? The Greek scholar and Latinist is living over in his pulpit the bygone centuries. He makes blunders over which the boy of eighteen in the school of technology must compassionately smile; and he puts his religion at a disadvantage by his ignorance.

The modern man believes that the great body of scientists are the world's truth-seekers. The searcher in science knows that if he but stumble in his hypotheses,—that if he but let himself be betrayed into prejudices or undue leaning toward pet theory, or anything but absolute uprightness of mind,—his whole work will be stultified, and he will fail ignominiously. To get anywhere in science he must follow Truth with absolute rectitude.

Comprehending this, the world recognises in its scientists a body of truth-seekers, whose only reward comes by clearness of thought. And the preacher who has spent long years in Latin and Greek, and knows next to nothing in science, need not wonder if he fails to hold the interest of his congregation,—perhaps it would not be improper to say, in some cases, the respect of his young men.

III. The Lawyer:—Talking recently with a noted lawyer, whose annual income exceeds the fifty-thousand-dollar mark, I was impressed with these words:—

"I have been obliged to sit through long hours of the night studying science. My university education was chiefly Latin and Greek. I am making amends for that blunder now by burning the midnight oil. I am called on to advise in large manufacturing operations where scientific questions come up at every turn. It is not enough to quote the law; if I would be of real service to my clients, I must have a true comprehension of their interests. I should say that I am valuable to them in about the following proportions:—

"Latin and Greek	0.1 per cent.
"Knowledge of the law	40 per cent.
"Grasp of scientific facts, and of organisation and of business relations	59.9 per cent."

IV. The Manufacturer:—The extent to which science enters into every branch of manufacture is almost immeasurable. A gentleman who was entering upon the production of an article which is a development of recent years, said:—

"To comprehend my work properly I should know 'what is in the heavens above, the earth beneath and the waters under the earth.' I must be able to anticipate the discovery of new forces; otherwise, something may come up to paralyse my investment."

Mr. Carnegie made his steel company by taking advantage of the latest discoveries in science. That manufacturer is undoubtedly the most far-sighted, and, other things being equal, will be the most successful, who possesses the most up-to-date scientific knowledge.

V. The Merchant:—The same conditions apply to the work of the merchant. Unless he keeps in touch with what is doing in the world of science, he may contract for articles this year which will have no value before they can be manufactured and delivered.

VI. The Business Man:—So also the general business man, or the man en-

gaged in transportation, in construction, *et cetera*. He can be highly successful only by being in advance. The more thorough his knowledge of science, the better equipped he will be to meet his competitors. To be able to write "De Pontibus" bears no relation in the point of advantage to the ability to reason out a new combination of particles of steel which will have a higher tensile strength.

VII. The Farmer:—He who goes out from his college elegantly accomplished in Greek expletives, and able while he guides the plow to hurl Latin oaths at his mule, bears no relation in efficiency to the scientist to whom every leaf and blade of grass unfolds itself in a wonderful invisible world; who knows the requirements of plant-life; the composition of soils; how to make a 12-inch ear of corn grow with twenty-two rows of grains where formerly the field yielded ears 10 inches long with only sixteen rows of grains.

VIII. The Doctor:—Just as medicine advances from the practise of ignorance upon credulity to a scientific study of the laws of health, so the necessity for writing Latin hieroglyphics will disappear into the realms of a distant charlatanry.

IX. The Artist:—The editor who handles art work is not infrequently compelled to regret the absence of scientific knowledge on the part of the artist. Mistakes that are almost foolish are constantly made through this lack.

X. Lastly, the Litterateur:—It is customary to say that a man acquires a knowledge of the English language by studying Latin and Greek. This is as true as if one were to say that in order to become expert with the small-sword one should practice at turning a grindstone. It is true that both require an exercise of the muscles.

The way to study one's own tongue is by reading the great masters who have written in that language. In them only the student finds those compact, forceful sentences, those nice shades of meaning, those delicate differentiations, those close synonyms, that brevity which is almost a necessary accompaniment of wit, and that elegance of expression which distinguish the best modern literary work.

Let the English student familiarise himself with the masterpieces in the English tongue, and he will, perhaps, save himself that stilted style, that laborious method and the affectations for which many noted Latin and Greek scholars who have left their work to the present generation are distinguished. One year spent in careful study of the best English literature is worth, to the intending author, four years of Latin and Greek.

If a man had at his disposal plenty of time to study all languages and science, too, it would be different. But no real worker is so situated. The average student has not one-tenth the time required for a profound education. He must, therefore, carefully select the course proportionate to the time at his disposal, and determine, not what would be best if he had endless hours, but what is best in view of the time allotted to him before the active work of his career must be begun. It is not too much to say that the author requires a knowledge of science at every turn, that the essayist becomes feeble and the novelist silly very often through lack of exact knowledge.

* * * *

How soon shall we see installed in our great universities boards of disinterested men of wide experience of life, knowledge of affairs, and freedom from fetish-worship, who shall have no connection with the active teaching or management of the colleges, and whose sole business it shall be to answer this question:—

What knowledge is of most worth?

INDUSTRIAL LOCOMOTIVES

FOR MINING, FACTORY, AND ALLIED USES

PART II.—COMPRESSED AIR AND INTERNAL COMBUSTION LOCOMOTIVES

By J. F. Gairns

THE use of compressed air as a motive power for locomotives has received the attention of inventors for many years; indeed, in the early days of the steam locomotive, "atmospheric" railways, as they were termed, bid fair, according to inventors and financiers, to be serious rivals of the steam engine, for several railways were actually built and equipped for compressed air working in Great Britain. In no instance, however, were they practically or commercially successful, and the atmospheric system soon disappeared. Nevertheless, in view of the cleanliness and handiness of compressed air locomotives and their adaptability to certain services, inventors have persevered, and several undoubtedly satisfactory machines were introduced on the New York elevated lines, for tunnel work, for tramway purposes, and, as will be seen hereafter, for mining and like use.

In consequence, however, of developments in electric traction, the compressed air locomotive has hardly had a fair chance. It is probable that had not electricity provided a remedy for the disadvantages and inconveniences of the steam locomotive in particular circumstances, the compressed air locomotive would have an established position on local railways and tramways and for miscellaneous use. For mining and factory work the pneumatic locomotive is eminently suitable, for it can be made very compact and can be very conveniently arranged as regards construction; there is no furnace to be a possible source of danger and to cause the emission of fumes and smoke; and it can be used in an explosive atmosphere. It has even been claimed that the use of compressed air locomotives in mines assists in ventilation and in the supply of pure air to the workings.

In single units, compressed air cannot be economically installed, but when there is an air-compressing plant provided for working coal-cutting and other machinery, and there is a number of locomotives to be supplied from the same central station, compressed air traction can be very advantageously introduced. There are many collieries in the United

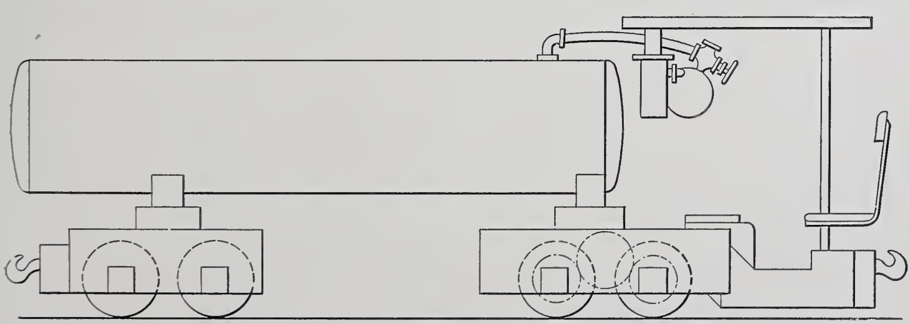


FIG. 27.—A COMPRESSED AIR MINE LOCOMOTIVE FOR A GERMAN MINE

FIG. 28.—A COMPRESSED AIR MINE LOCOMOTIVE BUILT FOR THE ASHLAND COAL & IRON RAILWAY CO. BY THE BALDWIN LOCOMOTIVE WORKS, PHILADELPHIA

FIG. 29.—A COMPOUND COMPRESSED AIR MINE LOCOMOTIVE BUILT FOR THE PHILADELPHIA & READING COAL & IRON CO. BY THE BALDWIN LOCOMOTIVE WORKS. NOTE THE SMALL AIR TANK ON TOP OF THE TWO LARGE ONES

States and a few in other parts of the world using compressed air locomotives, though in Germany electric traction is almost universal, and Great Britain possesses hardly any mines where locomotive traction is used at all. There is not much diversity in the design of such locomotives, and the building of them is principally confined to certain firms; but, as will be seen, considerable interest attaches to the designs in use.

The writer is not aware of any compressed air locomotives in use for any kind of work in Great Britain, or built by British firms, and on the continent there is a similar condition of affairs. There is one German mine, however, where the locomotive power is provided by compressed air,—pneumatic winding plants operated by underground compressed air engines supplied from compressors above ground are not uncom-

mon, but they do not come within our subject. Fig. 27 is a side elevation of the form of locomotive in use in this instance. As it possesses many noteworthy and unusual characteristics, it will be worth while to describe it more in detail than is generally possible in this article, the particulars being taken from the "Jahrbuch für das Berg und-Hüttenwesen im Konigreich-Sachsen," for 1894.

At the mine in question,—the "Alte Hoffnung Gottes" mine, near Freiberg, —compressed air was installed for working machinery in the mine in 1883, some old boilers being used as reservoirs below ground, and in 1891 a locomotive was introduced for bringing the laden tubs to the foot of the main shaft. The longest journey made by the locomotive is about 1000 metres; but the route is very irregular, and there are several almost right angular turns. The locomotive is mounted on two pivoted, four-wheeled bogie trucks, to provide for the requisite flexibility, the bogies being spaced 2.3 metres between centres. The main reservoir is 3.16 metres long and 0.7 metres in diameter, and air is supplied to it at a pressure of 12 or 18 atmospheres, the former pressure being used for the journey with empty tubs and the latter on the loaded trip. For use, the air passes to a small reservoir, and thence, past a reducing valve, to a double-cylinder, vertical engine, with cylinders 80 millimeters in diameter, of 200-millimetre stroke, and with a usual working speed of about 100 revolutions per minute, the air being used at a pressure of 4 or 5 atmospheres. The engine is mounted on one of the supporting bogies, and drives directly one axle, which is cranked, and drives the other axle of the same bogie indirectly by means of spur gearing arranged between the cranks.

The usual air pressure for use in the mine is only about 5 atmospheres, and for supplying the locomotive a small compressor has been fitted, which raises the pressure on either side of the compressing piston to 12 and 18 atmospheres, respectively, the air at one pressure being conveyed by pipes to the further limit of the locomotive route, and supplied at the other pressure to the locomotive adjacent to the compressor. The locomotive has limiting dimensions of height 1.6 metres (about 5 feet), and width about 1 metre. The gauge is 410 millimetres (about 16 inches). The usual load hauled by this little machine is four waggons, weighing about 14 cwt. loaded.

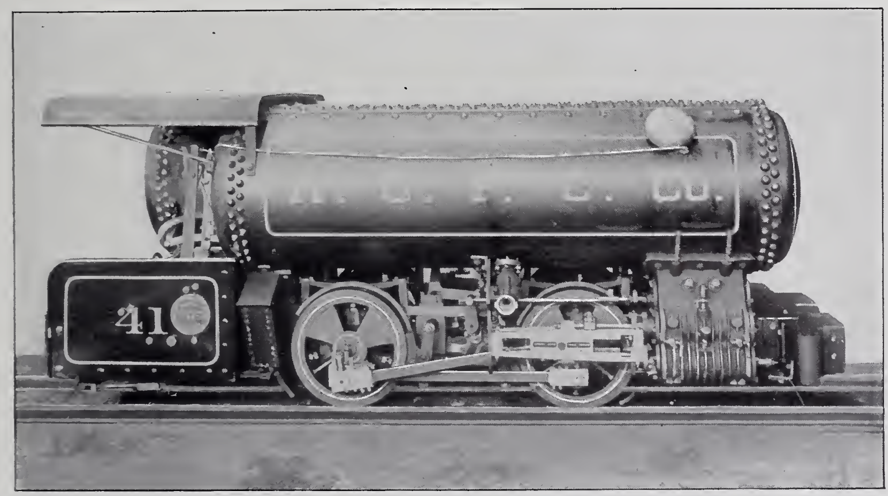


FIG. 30.—ANOTHER BALDWIN ENGINE. ONE OF THE AIR TANKS IS SHORTER THAN THE OTHER TO PROVIDE MORE ROOM IN THE CAB

In America the design and building

FIG. 31.—ONE OF THE H. K. PORTER COMPANY'S COMPRESSED AIR LOCOMOTIVES IN SURFACE USE FOR CONSTRUCTION WORK

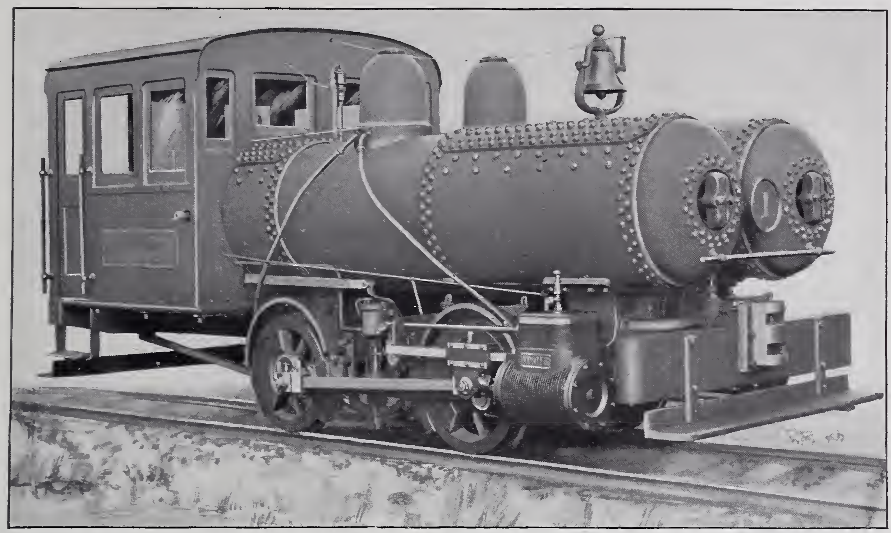


FIG. 32.—A HEAVY COMPRESSED AIR SHIFTING LOCOMOTIVE MADE BY THE H. K. PORTER COMPANY, PITTSBURGH, PA.

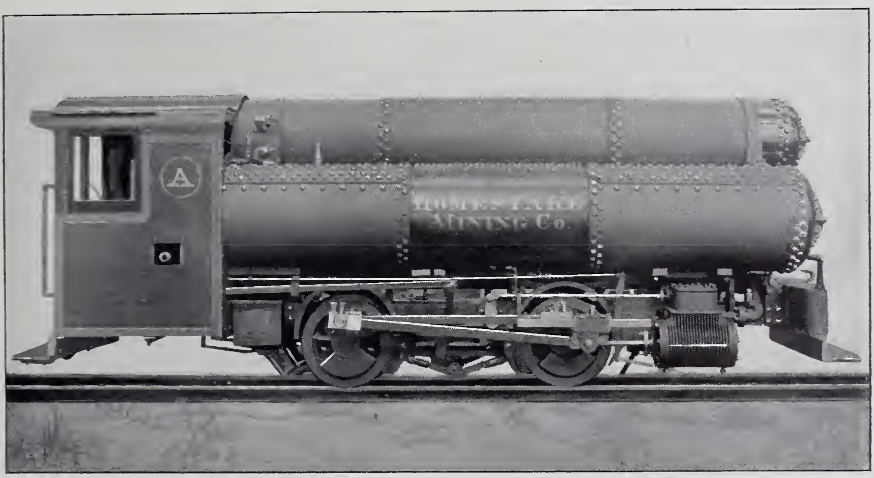


FIG. 33.—A HEAVY THREE-TANK COMPRESSED AIR LOCOMOTIVE FOR UNDERGROUND WORK IN THE MINES OF THE HOMESTAKE MINING CO. MADE BY THE H. K. PORTER COMPANY

of compressed air locomotives for mining service forms an important part of the business of the leading locomotive firms, more particularly the Baldwin Locomotive Works, of Philadelphia; the American Locomotive Company, of New York, and the H. K. Porter Company, of Pittsburgh.

The following notes from the latest "Record of Recent Construction," issued by the Baldwin Works, concerning compressed air mining locomotives, will be interesting:—

Locomotives particularly adapted to mine haulage were first used in the United States about the year 1870. These early locomotives were operated by steam, and proved vastly more efficient and economical than the prevailing system of hauling by animal power.

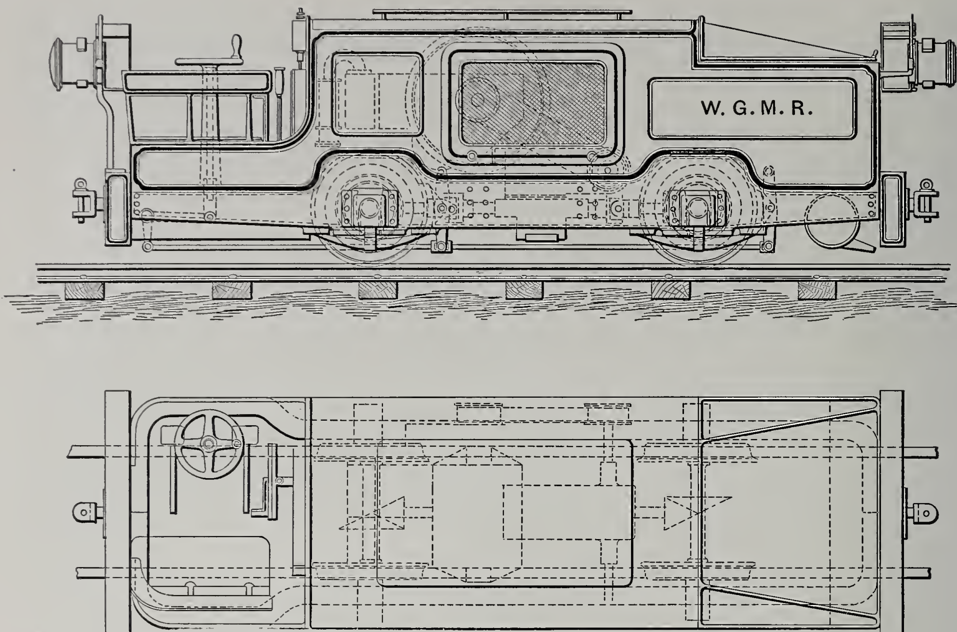


FIG. 34.—A SMALL PETROL LOCOMOTIVE BUILT BY THE WOLSELEY TOOL & MOTOR CAR CO., LTD., BIRMINGHAM, ENGLAND

Their use, however, was limited to the main gangways of well-ventilated mines on account of the danger and inconveniences from fire and escaping steam and gases. In order to overcome the difficulties attending the use of steam, compressed air was substituted. A reservoir was provided for the reception of the air, to take the place of the steam boiler, making no material change in the arrangement of the machinery. In this way the efficiency derived from the use of the locomotive was retained and danger avoided.

In the process of compression a large amount of heat is necessarily generated. This heat passes off and is lost as the temperature falls to that of the surrounding atmosphere. When the air is expanded in the locomotive a drop in temperature results, reaching far below that of the atmosphere; this has a marked effect on the final volume of the air used in the cylinders. An increase in economy and efficiency will, therefore, be obtained by restoring to the air some of its lost heat. An efficient system of reheating would be highly desirable were it not for the complication involved, and the fact that for mine service the process of reheating brings with it the very danger which the use of the compressed air locomotive is intended to avoid. It should be borne in mind, however, that the temperature of the expanding air falls far below that of the surrounding atmosphere, which, under these conditions, acts as a reheating medium by contact with the outer surfaces of the tanks and cylinders. Any increase, therefore, in the amount of surface of tanks or cylinders exposed to the atmosphere is a direct gain. In view of this fact, the outer surfaces of the cylinders are ribbed, causing them to present a greater area for absorption.

Within certain limits compressed air is preferable to steam or electricity for mine haulage. Compressed air locomotives, as compared with those using steam, differ but slightly, so far as the machinery is concerned. The steam generating apparatus is entirely eliminated, simplifying the construction and doing away with the part of the locomotive which requires the greater amount

of skill to operate. As long as the air supply is maintained, they are capable of handling the same load in proportion to their tractive power as locomotives operated by steam, and have the advantage of being entirely free from fire, gas or vapour.

With electricity, especially for large units, the trolley system is the only one ordinarily available, and the locomotive is confined in its range to that of the supply conductor, whereas with compressed air the locomotive is at liberty to run in any direction on any available track to the limit of its charge. The cost of installation for compressed air compares favorably with that for electricity.

It is possible to charge the locomotive direct from the compressor; but this system, although economical in some respects, would necessitate an increase in size of both the compressor and the locomotive. It is preferable, therefore, to provide stationary reservoirs at convenient points in the mine, from which a supply of air can be readily drawn to recharge the locomotive tanks. This enables the compressor to be run continuously and restore the depleted reservoirs to their normal pressure while the locomotive is doing its work. Where the system requires a considerable length of piping, the pipe line in itself will supply sufficient capacity without extra stationary reservoirs.

The charging stations should be located at convenient points, preferably at the ends of the run, or where the locomotive is, for other reasons, required to stop. This will economise the air by avoiding the necessity of running the engine any considerable distance simply for the purpose of recharging. The connection and stop valves for the charging stations are arranged with a view to ready adjustment and speedy supply, in order that the locomotives may not be detained longer than is absolutely necessary while receiving their charge. After the operation becomes familiar, the time required for making connections and recharging is ordinarily less than one minute.

A compressed air locomotive consists essentially of a storage tank mounted

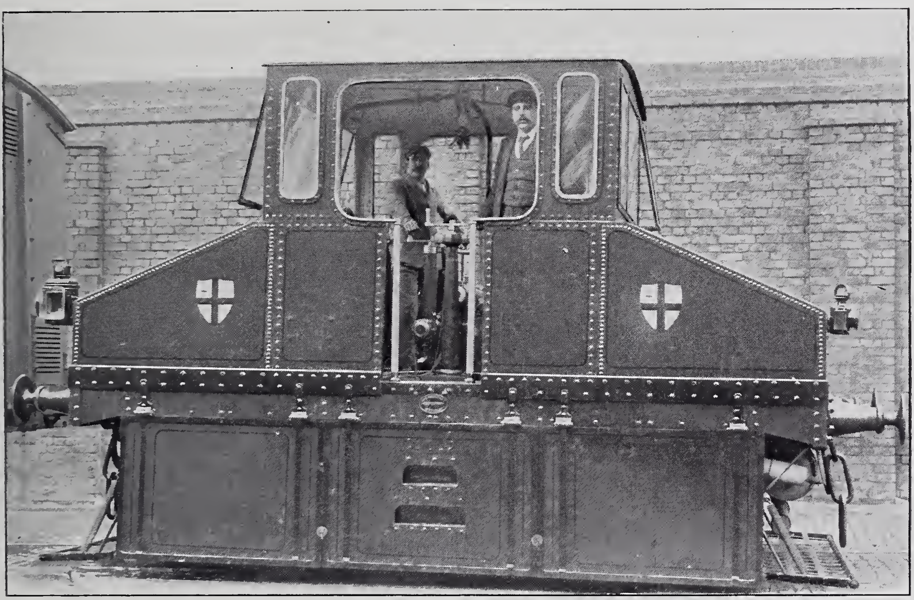


FIG. 35.—A PETROL SHUNTING LOCOMOTIVE MADE BY THE MAUDSLAY MOTOR CO., LTD., COVENTRY, ENGLAND

FIG. 36.—A MAUDSLAY PETROL LOCOMOTIVE AT WORK

upon driving wheels, with two engines to convert the pressure in the tank into direct motion at the wheels. The general details of construction and the materials respectively employed are similar throughout to those of locomotives operated by steam. One or more reservoirs or storage tanks may be employed, as may be found most suitable to meet prescribed conditions. Compound cylinders are sometimes applied to compressed air locomotives. With this system the cycle of expansion occupies a longer period of time for the same speed, and consequently a greater opportunity for heat absorption from the outside atmosphere is obtained.

One of the first compressed air locomotives to be put in successful operation was built by the Baldwin Locomotive Works for the Plymouth Cordage Company, of North Plymouth, Mass. The locomotive, one of small size, having a single tank and cylinders 5 by 10 inches, was ordered in 1876 and placed in service in April, 1877. It was used for general switching purposes and to transfer material from the storehouse to the factory, taking the place of four one-horse teams, with three men to each team.

The conditions of service under which the locomotive was required to operate were such as to preclude the use of steam. The fine particles of material with which the air was sometimes impregnated were highly combustible and no fire could be permitted, and the material under construction was liable to damage from the dampness occasioned by escaping steam. The compressed air locomotive, which was free from both fire and moisture, proved satisfactory to such a degree that another similar locomotive was ordered in 1894, and two others have since been placed in service.

As illustrative of American practice, two examples of pneumatic locomotives, built at the Baldwin Works, are shown in Figs. 28 and 29. There is no great variety among these locomotives, and so these examples will be sufficient for consideration in this article.

Fig. 28 shows a compressed air locomotive for the Ashland Coal & Iron Railway Company. There are three storage tanks, two of which are visible in the illustration, and a third, of smaller dimensions, is fitted between the frames. One of the large tanks is shorter than the other, to provide additional room in the cab. The air is stored at a pressure of 600 lbs. per square inch, and is used at 100 lbs. This engine requires a headway of 5 feet in height and 6 feet in width only. It will take curves of a 30-foot radius.

Fig. 29 illustrates a compressed air locomotive, compounded on the Vauclain system, as built for the Philadelphia & Reading Coal & Iron Company. In this engine, also, three storage tanks are provided, and the small one, from which air is taken for the cylinders, is distinctly visible in the illustration, above and between the larger reservoirs. Each low-pressure cylinder is above the high-pressure cylinder in one casing, and both are ribbed to facilitate the abstraction of heat from the atmosphere, as the air under pressure expands in doing its work The air is stored at a pressure of 600 lbs. per square inch, and is reduced to a working pressure of 200 lbs. The engine is of very reasonable dimensions, and is guaranteed to haul thirty-two trucks weighing one ton each on a grade of 1 in 60,—very good work for such a machine.

When used in the warm atmosphere of a mine and when properly designed, the chief drawback attending the use of air under pressure, namely, the liability to freezing as the air is expanded in use, is overcome, and these and dozens of similar locomotives are to-day doing good work in America and elsewhere. In practice it is found that the locomotives can work for considerable distances, and can stay away from the charging stations for comparatively long periods; they are, moreover, weight for weight, quite as powerful, if not more so, than corresponding steam locomotives.

Figs. 32 and 33 show a couple of double and triple-tank designs of the H. K. Porter Company, of Pittsburgh, one of the leading American makers of this class of locomotives.

FIG. 37.—A BLAKE LOCOMOTIVE IN SERVICE

FIG. 38.—A PETROL LOCOMOTIVE MADE BY F. C. BLAKE, OF KEW, ENGLAND, FOR THE RICHMOND MAIN SEWERAGE BOARD

INTERNAL COMBUSTION LOCOMOTIVES

The application of the principles of the motor road vehicle for the purpose of rail traction is an almost inevitable result of the ever-increasing introduction of the motor car, and the last year or two has shown that makers have realised the great possibilities of motor-car type vehicles for use on railways, and especially for shunting work, where the locomotive may lie idle for hours and yet be required at a moment's notice. Even for high-speed work light motor vehicles have been suggested, and numerous tramway and railway vehicles driven by gas and petrol engines have been advantageously introduced, notwithstanding the inconveniences and disadvantages,—as the steam locomotive engineer would term them,—attending the use of heavy gearing and multi-speed gears. But as shunting machines these vehicles are more convenient than steam locomotives, as they are always available for use and there is no furnace and boiler to require attention. They can also be used as single machines, whereas compressed air and electricity require central stations to supply the motive power.

For mining work,—gold mines, quarries, and surface work about collieries, etc.,—they have recently been introduced in several cases, and the prospects of their extensive adoption for such work, and for industrial applications generally, are exceedingly promising. The writer has investigated this subject thoroughly, and must thank various friends conversant with the work of motor-car builders for information, and the builders themselves for supplying photographs and particulars of the machines now to be described.

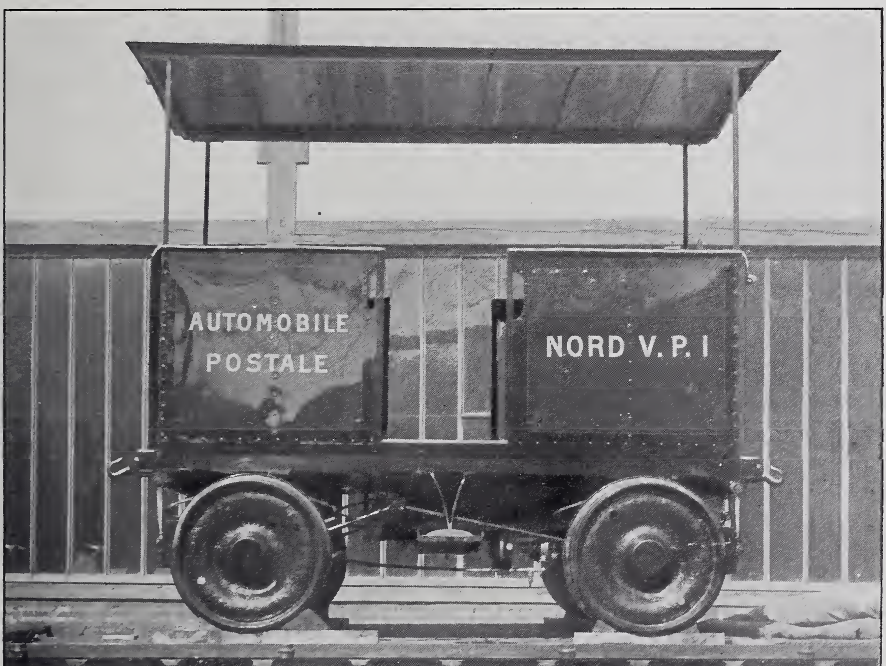


FIG 39.—A PETROL LOCOMOTIVE BUILT BY M. M. PANHARD & LEVASSOR, PARIS

Fig. 34 illustrates a small locomotive, of which several have been supplied by the builders and designers, the Wolseley Tool & Motor Car Company, Ltd., of Birmingham, England, for service in South African gold mines. It has a wheel-base of 4 feet 6 inches, and is designed for 18-inch standard light railway track. Its maximum height is 3 feet 6

FIG. 40.—A PANHARD & LEVASSOR PETROL LOCOMOTIVE FOR LIGHT RAILWAY SERVICE

inches, its greatest width 3 feet 4 inches, and its length over buffer beams 11 feet. The locomotive runs on four 18-inch wheels, all of which are drivers. The motor is of the two-cylinder, horizontal type. The engine develops about 20 horse-power. Three changes of speed in the gear box give four, eight or fifteen miles per hour. Powerful hand brakes are provided, and a water-cooled band brake is fitted to the high-speed countershaft. All operating gear, lubricators, ignition gear, brakes, etc., are well within the driver's reach, and he is accommodated with a comfortable seat looking across the engine. Petroleum and water tanks, of an approximate capacity of 30 gallons of petroleum and 40 gallons of water, are provided, thus enabling the locomotive to run continuously for well over ten hours. The whole of the mechanism is neatly encased by a detachable sheet metal cover, having conveniently situated doors for the ready inspection of all moving parts.

In Fig. 35 is shown a large shunting machine recently supplied by the Maudslay Motor Company, of Coventry, England, to the City of London Corporation for service in the Deptford Cattle Market. There are four coupled wheels driven by a Maudslay three-cylinder motor with cylinders 9 inches in diameter and of 9-inch stroke. The locomotive is capable of hauling a load of 60 tons on the level, but is only adapted for slow speed in shunting work, though two speeds are provided, as it has to travel sometimes through the public streets. In addition to powerful hand brakes, a vacuum brake is fitted. Fig. 36 shows this locomotive at work.

In contradistinction to this large and powerful machine, it will be interesting to consider a very small motor built recently by Mr. F. C. Blake, of Kew,

England, for use at the precipitation works of the Richmond Main Sewerage Board, at Mortlake, which is illustrated in Fig. 38, and is shown at work in Fig. 37. The locomotive is fitted with a Blake two-cylinder, 6 H. P. petrol motor, and all four wheels drive. The gauge of rails is 2 feet, 9 inches. There are two speeds, forward and backward, the locomotive being geared to run from three to seven miles per hour, hauling a load of 4½ tons up a gradient of 1 in 25, and 8 to 10 tons on the level. The weight of the engine is about 16 cwt. It is used on a short line from the precipitation works to the new private dock on the Thames side, and loads and unloads barges with sludge, coal, chemicals, etc. The average week's haulage is 250 tons, and the cost of petrol and lubricating oil amounts to about eight shillings per week.

The line is only a short one, but there is a good deal of shunting and the gradients are bad. A lot of time is taken up in waiting for a load, and this is where the petrol locomotive scores heavily over the steam locomotive. A common labourer or navvy drives it, as well as attending to the loading and unloading of the sludge.

The engine easily displaced two horses that were previously used at this work, and had been in use since November, 1902, with great success. The wheels are mounted in gun-metal-lined cast iron axle boxes, mounted in horn plates, with spiral springs between the boxes and the frame, the latter being of channel steel. The engine is put in and out of gear by a cone friction clutch, and gears are changed with finger or dog clutches, one or the other gear being always in mesh. The drive from the gear shaft is by a heavy roller chain, and both axles are coupled together by another chain and chain wheels. The greater part of the weight of the motor is placed over the leading axle. The driver is provided with a seat at the back, within convenient reach of the various controlling levers.

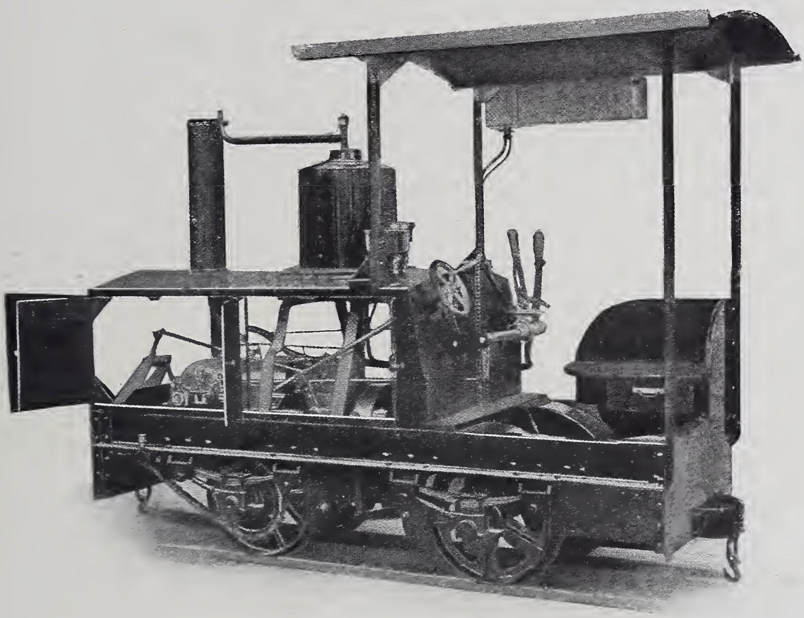


FIG. 41.—A PANHARD & LEVASSOR LOCOMOTIVE PARTIALLY DISMANTLED, SHOWING THE WORKING MECHANISM

The well-known French firm of Panhard & Levassor has also done a little

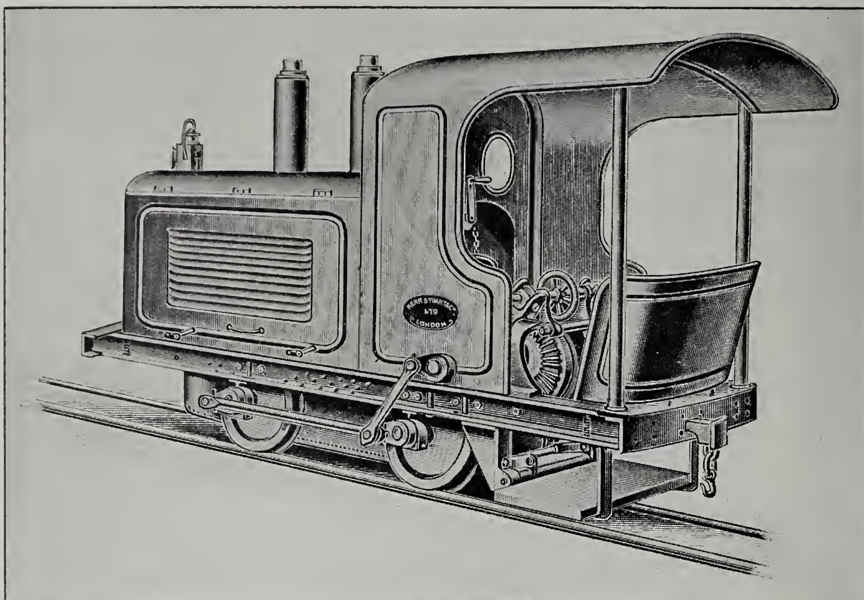


FIG. 42.—A PETROL LOCOMOTIVE BUILT BY MESSRS. KERR, STUART & CO., LTD., LONDON

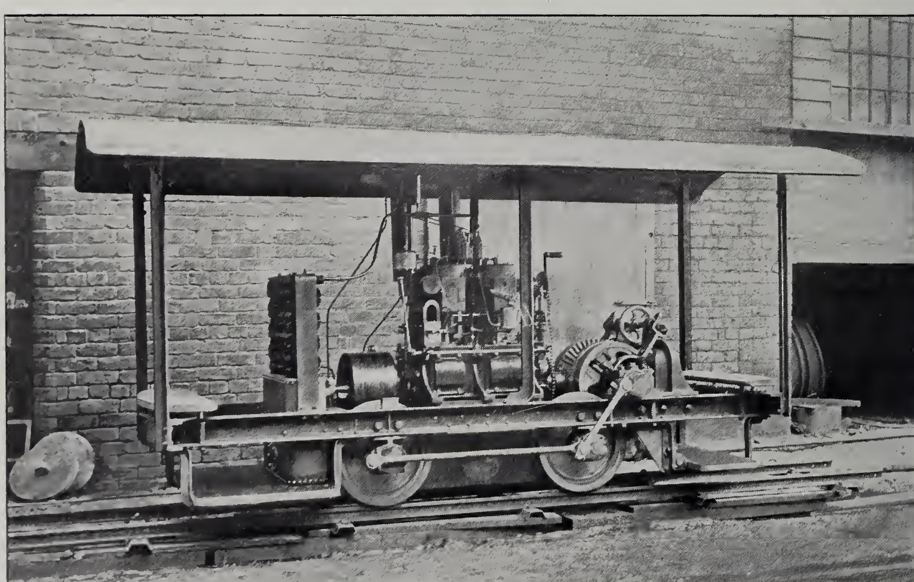


FIG. 43.—A PETROL LOCOMOTIVE,—OPEN TYPE,—BUILT BY MESSRS. KERR, STUART & CO., LTD.

work in this direction, and two of their productions are shown in Figs. 39 and 40, the one being intended for postal service and the other for light railway work. These machines are not strictly industrial machines in the sense contemplated by this article, but they are applicable to such work. Fig. 41 illustrates another form of petrol locomotive built by this firm, the covers being removed to show the mechanism. This block is reproduced from *Le Chauffeur.* The motor and gearing are of the same patterns as are applied to motor road vehicles built by this firm.

The locomotives described above have been produced by automobile builders; but the locomotive now to be considered has been built by a firm previously concerned, almost exclusively, with steam locomotives. Fig. 42 illustrates a very convenient internal combustion locomotive, or, as the builders style it, a kerosene locomotive, lately built by Messrs. Kerr, Stuart & Co., Ltd., of London, England. These engines are designed mainly for use on very light railways and for other work for which the ordinary steam locomotive is almost impracticable. They may be used on a gauge as narrow as 16 inches and on rails as light as 10 lbs. per yard, and can be worked equally well with either ordinary kerosene (petroleum used for illuminating purposes), petrol or alcohol. The consumption of kerosene is about 0.75 lbs. per brake horsepower per hour, and petrol or alcohol, in equal proportions. The main features of the locomotive, apart from details of the motor and gearing, with which we cannot at present deal, are shown by the illustration, and further description is hardly necessary. The mechanism can be enclosed in a suitable casing, and Fig. 43 illustrates a suitable closed construction adapted for use in circumstances where protection is necessary.

A few other petrol-driven motors have been built for running pleasure lines and for similar purposes, and such designs only require development to produce industrial machines suitable for mine and factory use. Inspection velocipedes and platelayer's lorries as used on railways are also in use in many parts of the world, and the writer has particulars of several of these, as built by the Simms Manufacturing Company, Ltd., of Kilburn, England, and other firms, though they hardly come within the field of the subject here.

Part I. of this article, in the July number, dealt with "Steam Locomotives." The concluding portion, next month, will be devoted to "Electric Locomotives."

MARBLE QUARRYING IN AMERICA

A NEW FIELD FOR ELECTRIC POWER SERVICE

By Day Allen Willey

THROUGH Southwestern Vermont flows Otter Creek, a stream of comparatively insignificant proportions, for the volume of water which it carries does not exceed a flow of 18,000 cubic feet per minute, except at flood height. It is notable, however, because it is the source of power which has helped, through electric conversion, in the development of the world's greatest marble industry, for from the deposits in its vicinity far more of this material is secured than from all other American quarries combined. While the output from Italy is more extensive, there are no individual industries in that or any other country of Southern Europe that compare with the operations of some of the single companies in Vermont. One enterprise alone produces from 60,000 tons to 70,000 tons annually.

Between the city of Rutland and the town of Proctor, in a distance of six miles, the stream has a fall of 165 feet. Advantage has been taken of this to install power plants which, utilising less than two-thirds of the average available volume of water, are employed for not only quarrying, but cutting and finishing the marble, and aid even the sculptor, who, with his pneumatic chisel, carves designs in the form of statuary and other objects which will well bear comparison with the craft of Carrara's artisans. While it is true that steam power also is available, this is merely auxiliary to the power obtained from the source referred to, and, in the near future, will be replaced entirely by the electric current. In fact, it is a question if a stream of this size has developed a more extensive industry anywhere else in the world.

It is somewhat singular that the value of this resource of New England has been so little realised that quarrying on a broad scale has been carried on only during a comparatively short period. Over a century ago blocks of marble were cut by hand from outcroppings, but the output until 1870 was so small as to be unimportant from an industrial point of view, although the deposits are located in one of the oldest settled portions of the United States, and one chiefly noted for its manufacturing interests.

When the variety and extent of the marble beds were, in part, discovered, the industry was rapidly expanded, until it now gives employment to 5000 men and represents an investment of $7,500,000 in capital, ranking third among the industries of the state named. While quarries exist in various portions of Vermont, from Isle la Motte, on Lake Champlain, to the southern border, the main centre of activity is in Rutland County, where the principal operations are controlled by one corporation,—the Vermont Marble Company. It is here that the interesting application of power referred to can be studied. The most extensive deposits now worked are at Proctor, where the main power plant is located; at Centre Rutland, three miles distant, where the secondary plant is situated; and at West Rutland, which is

THE TOWN OF PROCTOR IS THE CENTER OF THE VERMONT MARBLE INDUSTRY. ONE OF THE QUARRY OPENINGS IS SHOWN IN THE LOWER LEFT-HAND CORNER

A STORAGE YARD AT PROCTOR. THE BOOM DERRICKS ARE WORKED BY ELECTRIC MOTORS

erved by an electric transmission sysem four miles in length.

At Proctor the water is taken through a penstock, 9 feet in diameter and 225 feet in length, to two sets of turbine wheels installed in pairs. One pair develops 750 horse-power, which is served directly to the Proctor works. The second pair, direct-connected to electric generators representing 500 kilowatts, delivers an alternating current of 400 horse-power to the plant at West Rutland, at a voltage of 3500. It also drives a 75-kilowatt, direct-current generator for furnishing light and operating motors in use for various purposes at Proctor. The turbines connected with the generating units are operated under a head of 35 feet and the others under a head of 40 feet, being geared direct to the line shaft of the principal mill.

At the plant at Proctor, the direct water-power, as it may be termed, is used mainly in sawing the blocks as received from the quarries. Here again the creek is depended on to furnish the water, which is one of the principal cutting agents, as well as the power, the gang saws of soft iron working in the mixture of sand and water which is poured on the surface of the blocks. The gangs are set in framework attached to a wooden walking-beam belted to the line shaft, each gang carrying from five to twenty saws, according to the thickness of the slab desired. One inch is the minimum width cut. It is necessary to secure the sand from a bed two and one-half miles distant, and a cableway is used, equipped with 500-pound buckets having a capacity of 25 tons an hour. The cableway is built over a mountain, the rope being suspended from wooden towers, and the buckets carried by trolleys. About 25 horse-power is required for the sand carrier, and the balance not required for sawing is utilised for air compressors and for operating the smoothing tables and turning lathes and planers.

The secondary plant at Centre Rutland distributes its power by means of a rope drive, through electric generating sets, and by line shafting connected with

two of the turbine wheels. In the latter form, 150 horse-power is supplied under a 10-foot fall. The electric installation operates one mill. Here the water-wheels are connected with generators which serve motors for operating the marble finishing machinery, travelling cranes, as well as for lighting the buildings. The rope transmission is driven by one pair of turbines of 200 horse-power, working under a 30-foot head, and a 45-kilowatt generator for lighting purposes also is placed in the wheel house.

As more and more deposits have been opened in this region, the varieties found have been so numerous that material is available not only for every purpose for which marble has heretofore been employed in the United States, but new uses are being found for it as well. The industry is not confined to producing it in the rough or in cheap grades of work, but the finished product ranges from the block for the building base to statuary and vases, as well as interior decoration. Consequently, the industry is divided into a large number of branches, and in some of these the aid of electric power or compressed air has become indispensable. In the preliminary processes, however, water-power is mainly employed.

A QUARRY OPENING AT WEST RUTLAND, SHOWING THE MARBLE FORMATION AND THE BUTTRESSES LEFT FOR SUPPORT

It may be unnecessary to say that as sand and water are essential in the sawing of the marble, so they are required in removing the roughness of the surface preparatory to polishing. The surfacing or smoothing table consists of a circular iron plate revolved by means of an upright axle belted to the line shafting. The face of the marble is held firmly against the surface of this plate, which is covered with sand and water.

CHANNELLING MACHINES AT WORK

OPERATING ON A MARBLE LEDGE WITH STEAM AND ELECTRIC DRILLING AND CHANNELLING MACHINES MADE BY THE RAND DRILL CO., NEW YORK; THE INGERSOLL-SERGEANT DRILL COMPANY, NEW YORK; AND THE SULLIVAN MACHINE CO., CLAREMONT, N. H.

A 30-TON GANTRY CRANE IN ONE OF THE MARBLE STORAGE YARDS. MADE BY THE WHITING FOUNDRY EQUIPMENT CO., HARVEY, ILLINOIS

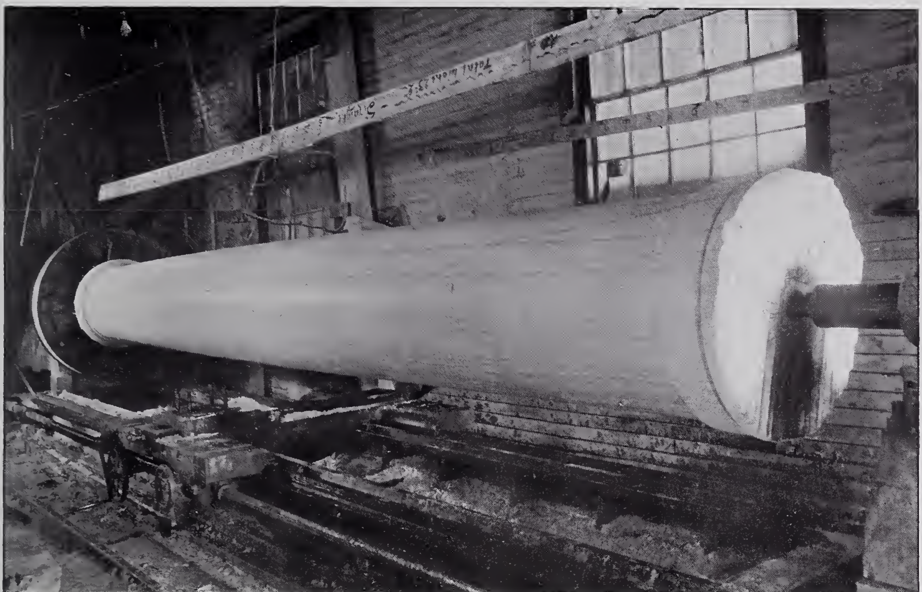
The polish which the surface of a piece of marble will take is one of the things which determine its quality, but the glossiest face is obtained only after repeated applications of different substances. Taken from the smoothing table, the marble block is placed on another similar device; but in this the surface is coated with pumice stone. From there it may be placed on a third, to be rubbed with another variety of pumice, and finally it is held against a buffing disc covered with felt. The best polished marble is the result of hand work, but the quality finished by machinery is such that a large quantity of it is turned out for hand railings for staircases, bank counters and interior walls.

The mechanism for working marble is so varied that a piece can be turned, planed and routed as readily as a piece of steel, entirely by power tools. The tool of the turning lathe is applied as in the ordinary metal turning lathe. In the Vermont plants can be seen circular columns weighing over 20 tons, exactly shaped by the power lathes, also globes, and tombstones containing ornaments in bas relief done with the planer. These machines are operated both by water-power and by individual electric motors.

The hand labour is another interesting feature of the industry. Undoubtedly the making of objects of art from marble has tended to increase the skill of the American artisan; but he has the assistance of the pneumatic chisel, and has become such an adept in its use that he can create designs not only beautiful, but extremely intricate, in a small fraction of the time needed with the mallet. Even the most elaborate figures in monumental work are partly if not entirely executed in this way. It may be added that a large number of Italians have been attracted to New England since marble finishing has become of such importance, although the experts

MARBLE BLOCKS FOR SHIPMENT

HIGH ART WITH THE PNEUMATIC CHISEL. THE VARIOUS PNEUMATIC TOOLS USED WERE SUPPLIED BY THE AMERICAN PNEUMATIC TOOL CO., NEW YORK



A MARBLE PILLAR, 24 FEET LONG, BEING FINISHED IN A LATHE

in the handiwork include the Briton and the Yankee as well.

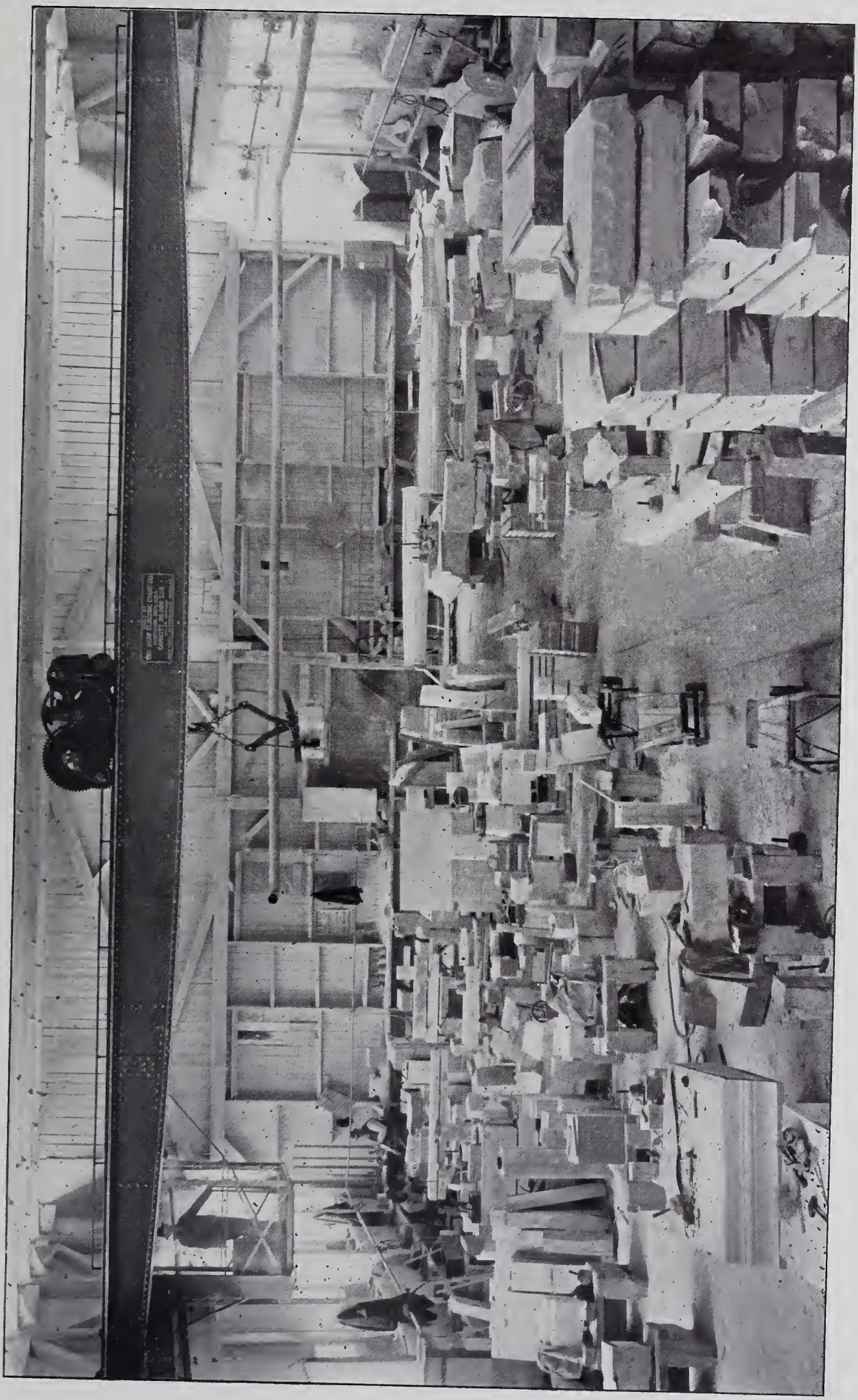
As blocks weighing 25 tons are taken from the Vermont beds, the method of storing and of transferring them from place to place is one of the most important mechanical features. For this electric power is extensively employed. One of the largest cranes used in the work is a gantry crane at West Rutland, serving the storage yard at that place, and having a total lifting capacity of 50 tons. It is shown on page 384. It has an overhang of 50 feet on either side of the track on which it is mounted. As this track is 60 feet in width, the crane can handle blocks in a lateral direction a distance of 160 feet, and can pile them to a height of about 40 feet. The bridge is moved by a 50 horse-power motor, and is equipped with two trolleys of 25 tons capacity each, the separate trolleys having individual 30 horse-power hoist motors. The track of a steam railroad extends under this crane to facilitate the loading and unloading of trains.

Another type of crane used is a half gantry of 15 tons capacity, also for train loading. It has 22 feet span, with a hoist motor of 21 horse-power, a trolley motor of 10 horse-power, and a bridge motor of 30 horse-power. Its outer end is supported by a steel tower moving on the ground rail, while the inner end rests on a truck mounted on an elevated track attached to one of the buildings.

All of the larger pieces in the various shops are also handled by cranes. In the building material mill at Proctor there is a three-motor electric crane of the same capacity and horse-power as the half gantry just mentioned. The voltage in each case is 220; this is true also of a yard derrick in use at Proctor, having an 8 horse-power motor.

The marble beds which are being most extensively developed have been located as far as Middlebury, in Addison county, on the north, and as far south as the town of Great Barrington, in Massachusetts, a distance of over 50 miles. So far as can be ascertained, the formation is continuous, but varies greatly in its distance from the surface. In Southwestern Vermont, where the bulk of the quarrying is done, openings have been made in a chain of foothills extending over a distance of ten miles. These are by far the largest quarries in the region. So much of the marble is

A VIEW IN A MARBLE SHOP, SHOWING THE USE OF POWER TOOLS IN SHAPING MARBLE BLOCKS



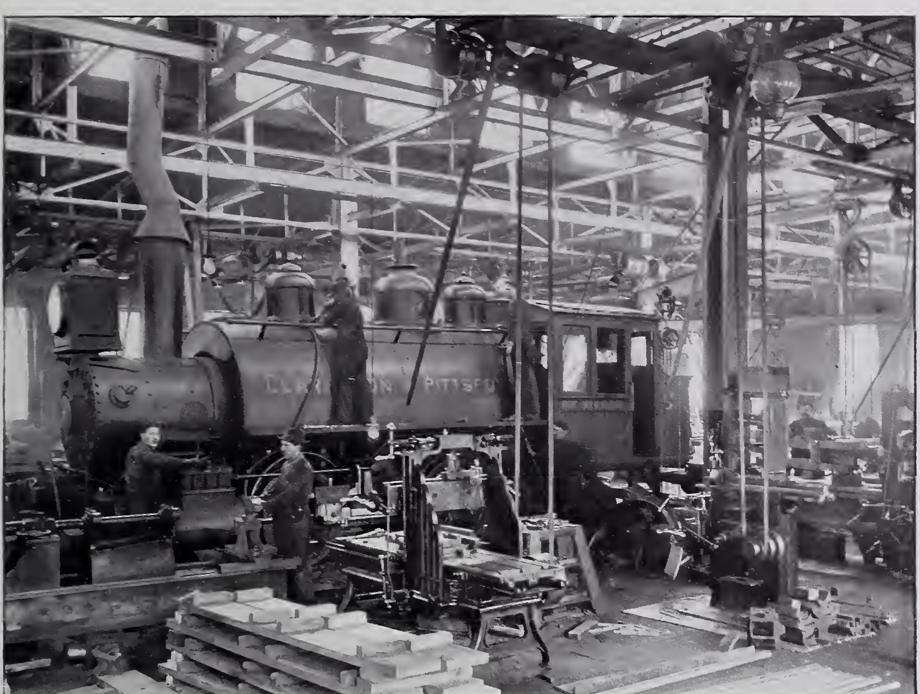
IN ONE OF THE FINISHING DEPARTMENTS. THE ELECTRIC CRANE HERE SHOWN WAS INSTALLED BY THE SHAW ELECTRIC CRANE COMPANY, MUSKEGON, MICH.

A 15-TON HALF-GANTRY CRANE AT PROCTOR. INSTALLED BY THE SHAW ELECTRIC CRANE CO., MUSKEGON, MICH.

available that operations are restricted to getting as many varieties as possible to fill the extent of the demand. Not one of these beds has thus far been exhausted, although at least one of them has been worked almost continuously for the last twenty years. Drill tests which have been made indicate the supply to be practically inexhaustible, and these conclusions are partly verified by the dimensions of some of the openings. Several of them have reached a depth of 200 feet without passing through any other substance. The bottom of the Sheldon Quarry, which is the deepest marble pit in the world, at present is fully 250 feet from the surface; but so far as it has been cut into, the floor and sides are of as good quality as any of the contents thus far extracted.

To a great extent, the marble is being mined rather than quarried, and far down the hills there are chambers so large that 5000 people could assemble in one of them without being crowded. In the Sheldon Quarry there is a series of excavations extending beneath the surface a distance of over 500 feet. Some of these excavations are 150 feet in width and 200 feet in height; yet the marble has been removed in blocks of such uniform thickness that the sides bear a remarkable resemblance to walls formed artificially of layers of the material. The beds vary considerably in their distance from the surface, and where a thick layer of rock and earth lies on the top, it is sometimes more economical to secure the marble by side openings or tunnels than to strip off the overlying material.

Explosives in marble quarrying in New England are used only when it is necessary to provide space for the quarrying machinery; consequently the waste from this cause, which is so large in the Italian industry, is here but trifling. Practically all of the material is separated by means of channelers and gadders. These machines are direct-acting and



THE REPAIR SHOP HANDLES ALL KINDS OF MACHINERY, RANGING FROM PUMPS TO LOCOMOTIVES USED IN AND ABOUT THE QUARRIES

travel backward and forward on a track. It makes a vertical incision 1¼ inches wide and from 4 to 10 feet deep, as may be desired, parallel with the rails and a few inches to one side. The machine makes but one channel or incision at a time, and works on the same principle as the common steam drill without the rotary motion of the drill. For cutting the channel five drills are clamped into a head, each one having a separate bit. These combined have the same result as if they formed one drill with five bits. With this machine in average operation, 100 feet of channel is not an unusual day's work, although the amount cut naturally depends largely on the hardness of the foundation. Another type of channeler in use may be called double-acting, as it cuts one channel on each side of the track and parallel with it.

The first-mentioned type is operated by steam, while the other is electric motor-driven, each machine having an individual motor mounted on the frame and direct connected to the shaft which drives the drills. The motors are of 8 horse-power, representing the same amount of power as when steam is utilised.

The channeling is done from the top downward, either directly or obliquely, according to the "grain" of the marble. For making lateral incisions to secure blocks smaller than of the channeled dimensions, gadders or drills are employed. The drills are of the usual pattern, operated by compressed air, while each of the gadders is driven by a 5 horse-power steam engine geared directly to the spindle. All of the work on the under side, however, is done by what is called the block-and-feather method. Into the material is driven a half-round piece of steel shaped like a carpenter's hand gouge. It is inserted with the concave side up, to a distance ranging from 6 inches to a foot, according to the size of the block. Immedi-

THE CHANNELLING MACHINES WERE SUPPLIED BY THE SULLIVAN MACHINE CO., OF CLAREMONT, N. H., AND THE STEAM STONE CUTTER CO., OF RUTLAND, VERMONT

ately above it another is driven, but with the concave side down, so that the two form a casing for a round wedge of steel, which is forced in. A row of these wedges is placed in the under side of the block and so loosens it that it can readily be detached with bars where the channels and the lateral incisions have been made.

As already intimated in the group of plants referred to, steam is utilised merely as an auxiliary source of power, for of the 2000 horse-power needed for present purposes only 200 are secured from steam. The electric distribution of water-power has been found so satisfactory that extensions are being made which, in the near future, will permit every portion of the equipment used in quarrying, hoisting and transferring the blocks, as well as the mechanism for finishing the material for commercial purposes, to be operated by electric motors and compressed air, only the sawing and preliminary surfacing being done by water-power direct.

As at present, the main power plant will be at Proctor. A series of three turbines, of 1000 horse-power each, will be substituted for the ones now in service. They will have a working head of 150 feet, the penstock being 9 feet in diameter and 400 feet in length Two wheels will distribute power to the Proctor plant exclusively, one operating a rope transmission system by which power will be conveyed directly to the sawing machinery and surfacers. A second will supply the works at West Rutland. It will drive a 750-kilowatt alternator, delivering a 3500-volt current, which will be "stepped up" to 10,000 volts. This will be sufficient to operate all of the West Rutland apparatus. The third wheel will be direct-connected to a 500-kilowatt alternating generator and to one direct-current generator of 250 kilowatts. The latter will

be utilised for lighting as well as power purposes, while the former will be employed for power exclusively. As the plant at Centre Rutland will be operated by its own power supply, nearly 3500 horse-power will be secured from this comparatively small volume of water when the improvements are completed. As this company quarries mines and prepares for market over 90 per cent. of the marble which comes from Vermont, it may be said, with good reason, that the marble industry of America centers about this stream.

AMATEUR ENGINEERING

By Egbert P. Watson

IT is a curious trait of human nature that leads some men to undertake the conduct of engineering enterprises when they have never had the least experience of any kind in such work. They may not have even read of or studied what has been done, or what it is possible to do, and are often as unacquainted with practical mechanics as a student in his first year. It would seem that common prudence might suggest that there are difficulties in the way of success to prevent them from realising their expectations, but this seems never to occur to them.

There is a case in point which occurred within the writer's own experience. A man conceived the idea of installing electric lights in his country house, and, not having a great deal on his mind, thought it would be a very simple thing to occupy his leisure in this way. To this end he applied to a firm of engineers, laid before them his requirements, and asked what they would undertake the work for. They named a sum which seemed to him an exorbitant one.

"It cannot possibly amount to any such figure," he reflected, and, to satisfy himself upon this point, began inquiring around among manufacturers for the different details. The dynamo was quoted at so much by one firm, but another one bid much lower; so, without any knowledge of the capacity of the two kinds, he decided that the cheapest was the best, and ordered that.

The engine was the next thing, and he purchased one "guaranteed" to do certain things, but he did not bother with investigating the guarantors; for there is much virtue in a guarantee,—like charity, it covers a multitude of sins. The same course was pursued with other details, including the boiler, the projector of the scheme here outlined being apparently of the opinion that setting up an electric light plant was akin to ordering furniture from a department store and arranging it to suit his views of what was proper under the circumstances.

Collecting the several details was an affair of many months,—running into years, in fact,—for with no one behind the purchaser to see that the promises made for delivery were kept, and protected by advance partial payments against the orders being countermanded, the sellers took their time, and the buyer learned a lesson in patience under difficulties.

Everything has an end, however, though the upshot of the matter was a misfit all around, as might have been expected under the circumstances. The boiler was too small for the work to be done, though it was what the buyer had called for. He had specified one of 25 horse-power, but under ordinary load and pressures the engine worked up to as much as 35 horse-power. Moreover, when complaint was made that the boiler was inadequate, the maker declared that it was based on standard requirements

and would deliver its rated horse-power with proper care and management if the engine were also of standard rating. Whereupon the owner was moved to say that the latter was all right, it being guaranteed to deliver a horse-power for "forty-five pounds of water" per hour. The response to this was that the boiler was too small by 50 per cent. if the engine required that amount of steam per hour per horse-power, and that it was not the boiler maker's affair. The rest of the outfit was burdened with troubles of similar nature.

In the interval which transpired between the inception of the plan and its final execution great improvements, moreover, had been made in electric lighting plants, so that if everything had really worked as it should, the man still would have had an obsolete outfit. The natural reflection is that the man was unwise; for in cases like the one related it is not only the first step which costs, but all the subsequent steps as well. A reliable firm of engineers would have given him perfect satisfaction in the premises, and he would have had value for his money.

Some may think that this is an exceptional case, but that is not so. Similar instances occur constantly in many places. Here is another case:—

A firm of manufacturers had outgrown their facilities and were compelled to enlarge their shops. There was plenty of room all round them to do just as they pleased; but being without experience, or foresight in regard to the future, they got into a curious position. One of the partners had been a salesman, and while he managed his end successfully, he was out of his element when it came to designing new shops. Still he went at the proposition without hesitation. The other partner was the manager of the works, but without practical experience as a workman himself.

Discussion arose as to what should be done, and the former salesman made a rude plan of the new buildings, showing where they were to be put. The manager at once disapproved of it, and insisted that a certain shop should be as close as possible to the old ones so as to avoid carrying the work back and forth and to shorten the journeys as well; but they finally agreed on a causeway about 54 inches wide between the shops, "so that a team could get in," said they,—and the shop was so placed. Why they assumed that a horse and cart could manœuvere in such a contracted space will never be known; but they did, nevertheless, only to find later that about 3 feet more width would have been none too much.

The new shop was lighted by large windows on both sides, with no other provision for light, and, being two stories in height, skylights were impossible for the lower floor.

The reader may anticipate what eventually happened. Another firm in time bought land alongside the new shops, and proceeded to build as close to them as the law allowed. The result was that the first firm named had to resort to artificial light, while the newcomers erected one-story shops with skylights.

But this was by no means the end of misadventures, for it was discovered, when the extended works were to be occupied, that they were surrounded on three sides by the newcomers, and there was no outlet for shipping anything that required cartage. The only remedy was to remodel the front of the main building, rearrange all the machines that bordered upon it, and cut a large front door to receive and deliver goods of weight and bulk, of which there were many. It necessitated, further, reversing the order of one shop or the other, —one of them was wrong end to. No one had ever contemplated such a condition of things as then existed, but it suddenly confronted them.

All the material had to be carted or carried through the main shop, piece by piece, before it reached the machines, and there were so many of these that when a man stooped over he bumped into the other man behind; it amounted, in fact, to remodeling the works after they had been remodeled, and the confusion which existed, to say nothing of the cost, was very great. Upon the principle that the first loss is the least,

it would have been easier and much more desirable in the end to have abandoned the works and erected others elsewhere, for, in the new lay-out, everything was wrong and always would be.

This disaster, for such it was, could have been wholly avoided by taking counsel of engineers competent to carry out such work. They would, as a matter of course, first have inquired into the tenure of the present occupants of the holding, and found out their actual status. They would have foreseen the possibility of being crowded out of all essential facilities by other parties occupying adjacent territory; they would have considered the reception and delivery of raw and finished goods, and would have given the proprietors a factory which would have helped rather than hindered their operations. From want of experience and entire ignorance of the importance of their undertaking the owners acted as their own counsel, and there are a great many others today contemplating the same unpardonable error.

Another case is that of a man who had a "speaking acquaintance," if we may so term it, with mechanical matters, but very little practical experience. He had to take a so-called house-heating boiler in return for a bad debt, and straightway conceived the idea that a cheap way to warm his house would be to buy a lot of pipe and fittings and install them himself. Acting upon this impulse, he purchased heaters or radiators, traps, and the valves needed for the purpose; but, like his predecessors in other directions, he also came to grief.

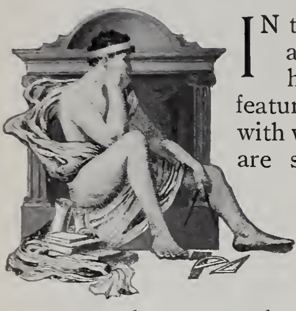
One would have thought that the holes in the radiators would have been some guide as to the sizes of pipe to be used on them; but this man knew better, and bushed some of them, because, from his point of view, they were too large, certainly too large for the pipe he had bought without first seeing the radiators.

When he started to erect the risers and returns he began to have trouble; he had to acknowledge to himself that he did not know how they should be run, but his pride forbade a recourse to the trade, so he put up something, as near as he could guess to what it should be, and let it go at that. When he came to test his job the results were disappointing. He had not packed a single valve, neither had he properly made up the pipe joints, and every one of them leaked. The water ran down every crevice in the floor of every room and spoiled the ceilings below. Some of the air valves had been omitted, and the steam blowing through filled the house; in a word, he had a botch job throughout. The boiler itself was defective in that it had a cracked crown-sheet, and the repairs would have cost almost as much as a new one. All this annoyance and loss was incurred by amateur engineering.

James Nasmyth, the well-known English engineer, defined engineering as "common sense applied to the use of materials," but a man may be well gifted with that quality and still fail of success. A man may possess all the common sense there is in the market, but if he lacks experience, he will wallow in the mire when he comes face to face with unfamiliar propositions. Amateur engineers are jacks-of-all-trades and masters of none; they are distinctly out of place in tasks that require serious treatment.

INVENTORS AND CURIOUS INVENTIONS

By Georg Kirkegaard



IN this age of inventions, a model-maker's work has some interesting features, and the problems with which he is confronted are sometimes very perplexing. Everybody nowadays seems to be an inventor of greater or less degree. Inventions of to-day are not always the result of necessity, but seem more often to be the result of vain attempts to gain wealth or notoriety. As a matter of fact, very few inventors gain either of these ends.

There are many different types of inventors, real and so-called:—First, the typical or born inventor; second, the practical inventor, whose invention is evolved from practical experience; third, the man who imagines he is an inventor, but has not the least idea as to how he may accomplish his end; fourth, the inventor in name only, who takes advantage of others' ideas, or rather puts his name to inventions which others have created, and who, for this reason, is often not able to explain the invention or patent to which his name is attached; fifth, the woman inventor; sixth, the crazy inventor; seventh, another that probably should be included with the sixth class,—the perpetual motion inventor. Last, but not least, we may name the fraud inventor, who invents only to cheat and defraud. The last three classes are not recognised by the patent office, but they flourish to a great extent nevertheless.

The first question asked of the model-maker by an inventor who wants his idea practically demonstrated is, "What will it cost?" Then the model-maker is told that the inventor has not much money to spend on the first model, but after that is made "there will be millions in it." As a general rule, before even the first model has been made the model-maker is requested to give an estimate for many thousand machines, and very often a fine position as superintendent or something else, with a big salary, is held up for him as a special inducement to do his best.

All this is a common occurrence, and when an inventor does not introduce himself in the manner described, he proves, as a general rule, to be of the practical type. These inventors know what they want, and, as a rule, have worked out drawings and plans before calling on the model-maker. Business with them is soon arranged.

The man who pretends to be an inventor, but profits only by others' inventions, is very troublesome, and in most cases is unable to explain the working of his inventions. As a general rule, he has money, he knows what he wants to accomplish, but by what means he has no idea; he is, however, willing to pay for the work. The writer remembers a case in which Mr. M. visited his office one day to see him about making a model of a nickel-in-the-slot machine for selling tickets at railway stations. Mr. M. showed several complicated sheets of patent office drawings, and without asking the cost, etc., told the writer to go ahead. The writer looked over the drawings and asked for some explanations of construction. Mr. M. looked at him with astonishment and said, "Don't you understand a drawing?" To the reply that an explanation would simplify matters, Mr. M. answered that it was so long since he had invented the machine that he had forgotten all about it.

The truth was, that he was not himself the inventor of the machine. How-

ever, as he was willing to pay for expert service, the machine was completed and worked to perfection. This same man had a safe full of patents, all with his name as inventor; but of all those he had probably not invented a single one.

The people who want to invent, having no definite idea as to what they want or how to accomplish it, are not numerous; still they exist, and, as a rule, they also have money. As an example, a man wanted to invent a new street-sweeping machine. This machine should not only clean the street and gather up all dirt, but should also at the same time assort the different kinds of refuse, such as paper, wood, etc. To the writer's question if he had a drawing showing the construction, he answered, "No. That is why I came to you." He also wanted to know what it would

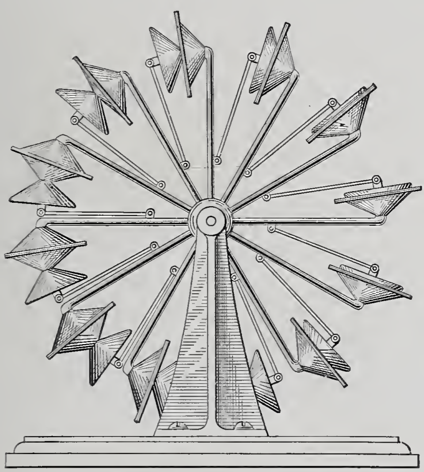


FIG. I.—A PERPETUAL MOTION MACHINE

cost to build such a machine. Model-makers have not much time to spend on that kind of inventor.

Women inventors are quite numerous, and their inventions are generally household articles or toys, often very ingenious. It is in most cases difficult for them to explain their ideas, and in regard to cost of making models, they can never understand why these should be so expensive. However, as a rule, they are honest, and pay their bills.

The crazy inventor we find now and then. He has a high opinion of his own ability, and is always ready to improve on anything he sees. The writer once did considerable work for such a man, and to mention all his ideas would fill a book. Among his pet ideas were:—A machine which, by wireless current, could kill an army fifty miles distant; a chemical process for making milk out of blood; a machine for making pliable glass; a war balloon propelled by exploding gunpowder in the same fashion as in a skyrocket; a projectile for heavy ordnance provided with ball bearings; a transatlantic telephone, harbour fortifications, and numerous other schemes. This inventor had no knowledge of mechanics whatsoever, either practical or theoretical. It was simply a hobby with him to invent, and the more impractical his ideas were, the more he thought of them.

Perpetual motion inventors are not as numerous as in years gone by; still we find them occasionally. The most ingenious idea in perpetual motion machines to the writer's knowledge is shown in Fig. 1. It is simply a wheel composed of twelve arms of thin tubing. On the end of each arm is a conical, cup-shaped receptacle covered with soft sheet rubber. On the outside and in the centre of the rubber covering is fastened a weight of the same conical shape as the cups. All the tubes are connected to the hollow axle. After having the wheel well balanced, one of the rubber caps is removed and water is poured into the wheel until half of the cups and tubes are filled, and the cap is then replaced.

It will now be seen that the idea was by aid of the weights to force the water over to one side, thereby always having a surplus of weight on one side of the centre of gravity, this causing the wheel to spin around. Many able engineers looked at this machine, and although they knew beforehand that the scheme was an impractible one, they took quite an interest in the experiment, which proved to be only an addition to former failures in perpetual motion machines.

Of fraud inventors the writer has had

experience with several, one of whom cheated not only the public, but the writer as well, the latter having made several parts of the device, not knowing for what purpose it was to be used. This man had his machine exhibited at a summer resort. It consisted of a large board divided into small squares; on some of the squares was fastened an article, such as a pipe, knife, etc. Each square rested on a hinge, and was controlled by a magnet operated by a push-button in a battery circuit.

As each square had its own push-button, there were about 200 of the latter located on a table in front of the large board with all the different articles exhibited. The game was as follows:—For a certain coin one could select a push-button, not knowing to which square it was connected. By so doing and making electrical contact, the corresponding square would fall down on its hinge, and if a prize were fastened to the square, the lucky winner would receive it. All would have been right if fraud had not been introduced; but the operator had a private connection, and at will could let his victim win or lose. The same scheme is practiced in gambling-house games, about which we often read in the daily papers.

Turning now to curious inventions, a phonograph which works by its own weight, is a fair example of this class. This machine has no clock spring, no leading screw and no regulator,—three parts indispensable in all other machines of this class. It works on an incline about 5 inches long, and its own weight operates the mechanism. While sliding down the incline the cylinder rotates, and the speed is regulated according to the pitch of the incline. The membrane or reproducer is stationary. In order to repeat the operation, it is only necessary to push the machine up to the top of the incline. This novel phonograph is contrary to all other known constructions, and is correspondingly curious.

Another novel phonograph is the so-called telegraphone, of which the writer was the first maker in the United States. In this machine the human voice is recorded and again reproduced on a steel wire or ribbon. The sound waves, even to the faintest whispers, are recorded by magnetic influences, and are, if necessary, permanently impressed on the steel wire.

The operation of the telegraphone is very simple:—A steel wire passes in front of a small electro-magnet, which is connected to a transmitter and a few dry cells. All the impulses from the transmitter react through the magnet upon the steel wire and give it a permanent magnetic impression. In order to reproduce the record so made, it is only necessary to replace the transmitter with a receiver, and let the wire again pass before the poles of the magnet. The magnetised wire will now react, through the magnet, on the telephone receiver, and the original sound is reproduced.

Fig. 2 is a diagram of the first telegraphone ever made in the United States. It consists of a wheel of brass, on the periphery of which are about 2000 permanent magnets, made of thin steel, and laid side by side. The recording

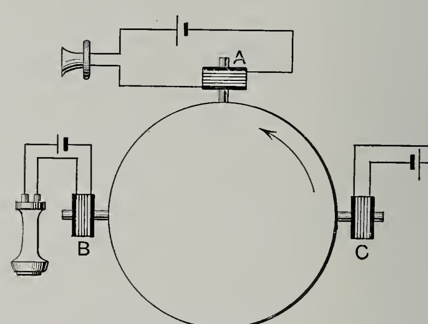


FIG. 2.—A DIAGRAM OF THE FIRST TELEPHONE MADE IN THE UNITED STATES

magnet *A*, to which a transmitter and battery are attached, is placed at the top of the wheel, with its poles opposite those of the permanent magnets. Another magnet *B*, to which a receiver is attached, is placed on the side in front of the wheel. The magnet *C* is the effacing magnet.

If a word be spoken into the transmitter, the fluctuations of current will cause the recording magnet to impress the small magnets on the wheel while

the wheel is rotating in the direction of the arrow, and the word will be reproduced by the receiving magnet and the receiver on the side when the portion of the wheel impressed arrives at that point. But when the wheel passes the effacing magnet the magnetic impressions are wiped out, and the small magnets are ready to receive a new record.

One other invention worth noting is a wireless electric typewriter. The transmitting machine consists essentially of a disc rotating in synchronism with a similar disc at the receiving station. Electro-magnets on the disc, one for each letter, are controlled by the typewriter keys. Pressing down a key on the transmitter operates a lever which engages with a certain contact piece on the rotating disc when the latter is in a definite position, contact is made, the magnet is excited, and the letter is printed. At the same instant an electric impulse is sent into space. This is received by the other instrument, and, the disc on the latter being in a similar position to that on the transmitter, the letter is again printed. By means of a controlling key the apparatus at the receiving station may be started or stopped simultaneously with that at the transmitting station.

This machine is still in the experimental stage, but the inventor has great hopes for its future. The advantages of such a system, should it prove commercially successful, are manifest. In these days time is of great importance, and with this instrument a saving of two-thirds of the time of transmission is claimed over that of the wireless telegraph.

INSULATOR PINS FOR TRANSMISSION LINES

By Alton D. Adams

INSULATOR pins are among the weakest elements in many electric transmission systems. As line voltages have gone up it has been necessary to increase the distances between the outside petticoats of insulators and their cross-arms and to lengthen the insulators themselves in order to keep the leakage of current between the conductors within permissible limits. To still further reduce the leakage, the wires on many lines have been located at the tops instead of in the old position at the sides of their insulators.

All this has tended to a large increase of the mechanical strains that operate to break insulator pins at the point where they enter the cross-arm, because the strain of each line wire acts with a longer leverage. Again, it is sometimes necessary that transmission lines make long spans across rivers or elsewhere, and a very unusual strain may be put on the insulator pins at these places.

As long as each electric system was confined to a single city or tower, a broken insulator pin could be quickly replaced, and any material interruption of service from such a cause was improbable. Where the light and power supply of a city, however, depends on a transmission line many miles long, as is now the case in many instances, and where the line voltage is so great that contact between a wire and a cross-arm will result in the speedy destructon of the latter by burning, a broken pin may easily lead to a serious interrupton of the service.

Besides the increase of mechanical strains on insulator pins, there is the danger of destruction of wooden pins by charring, burning and other forms of disintegration due to leakage of current over the insulators. This danger was entirely absent in the great majority of cases so long as lines were local and operated at only moderate voltages.

These several factors combined are bringing about marked changes in design.

On straight portions of a transmission line the insulator pins are subject to strains of two principal kinds. One of these is due directly to the weight of the insulators and line wire, and acts vertically to crush the pins by forcing them down onto the cross-arm. The other is due to the horizontal pull of the line wire, which is often much increased by coatings of ice and by wind pressure, tending to break the pins by bending, — most frequently at the point where they enter the cross-arm. A strain of minor importance on pins is that encountered where a shortpole has been set between two higher ones, and the line at the short pole tends to lift each insulator from its pin, and each pin from the cross-arm.

Where the line changes its direction, as on curves and at corners, the side strain on pins is greatly increased, and such places give by far the largest amount of trouble through the breaking of pins. The latter seldom fail by crushing through the weight of the lines they support, because the size of pin necessary to withstand the bending strain has a large factor of safety as to crushing strength. Insulators are sometimes lifted from wooden pins, and the threads of these pins are stripped where a short pole is used, as already noted; but failure of this kind is not common.

Iron pins are either screwed or cemented into their insulators, but the cemented joint is much more desirable, because where a screw joint is made the unequal expansion of the iron and the glass or porcelain is apt to result in breakage of the insulator. Where cement is used, both the pins and insulators should be threaded or provided with shoulders of some sort, so that, although the shoulders or threads do not come into contact with each other, they will, nevertheless, help to secure a better hold. Pure Portland cement, mixed with water to a thick liquid, has been used with success, the insulator being placed upside down and the pin held in a central position in the hole of the insulator while the cement is poured in. Another cement that has been used for the same purpose is a mixture of litharge and glycerine. Melted sulphur is also available.

The same forces that tend to lift a pin from its insulator tend also to pull the pin from its socket in the cross-arm or pole top. With wooden pins the time-honoured custom has been to drive a nail into the side of the cross-arm so that it enters the shank of the pin in its socket. This plan is good enough so far as immediate mechanical strength is concerned, but is not desirable, because it is hard to remove a nail when a pin is to be removed, and also because the rust of the nail rots the wood and tends to lower the insulation. A better plan is to have a small hole entirely through each cross-arm and insulator pin at right angles to the shank of that pin in its socket, and then to drive a loose wooden pin entirely through from side to side.

TABLE I.—DATA OF LINES ON WOODEN PINS

Location of the Lines	Circular Mils of Each Conductor	Feet Length of Span Between Poles	Inches from Wire to Shank of Pin
Colgate to Oakland......	†133,100	...	13
Electra to San Francisco.	*471,034	130	15
Canon Ferry to Butte...	†105,600	110	13½
Shawinigan Falls to Montreal	*183,750	100	16¼
Niagara Falls to Buffalo.	†350,000	70	7½
Niagara Falls to Buffalo.	*500,000	140	10
Chambly to Montreal....	†133,100	90	8½
Colgate to Oakland......	*211,600	...	13

* Aluminium conductors.
† Copper conductors.

Some of the most important factors concerning the strength of insulator pins vary much on different transmission lines, as may be seen from the following table of lines on which wooden pins are used. On the older line between Niagara Falls and Buffalo, the regular length of span is 70 feet, and each copper conductor of 350,000 circular mils is attached to its insulator 7½ inches above the point where the shank of the pin joins its stem. On the new line the length of span is 140 feet, and each aluminium conductor of 500,000 circular mils is attached to its insulator 10 inches above the junction of the shank and stem.

To compensate for the greater strains

introduced by doubling the length of span and using pins of longer stem, the diameter of the shank of the new pins was increased to 2 inches. One line between Colgate and Oakland is of copper, and the other is of aluminium conductors, but the same pins appear to be used for each. On the line between Cañon Ferry and Butte, in Montana, U. S. A., the pin used in pole tops has a shank $2\frac{3}{4}$ inches longer and $\frac{1}{8}$ inch greater in diameter than the pin used in cross-arms. The weakest pin included in the table seems to be that in use on the line between Chambly and Montreal, which is of hickory wood, about $1\frac{1}{2}$ inches in diameter at the shank, and carries its No. 00 copper wire $8\frac{1}{2}$ inches above the junction of shank and stem.

TABLE II.—DIMENSIONS OF WOODEN PINS IN INCHES

Location of Lines.	Length of Stem.	Length of Shank.	Diameter of Shank.	Diameter of Shoulder.	Diameter of Threaded End.	L'gth of Threaded Part.
Colgate to Oakland	10⅜	5⅜	2⅛	2½	1⅜	2
Electra to San Francisco	12	4⅞	2¼	2¾	1⅜	2
Canon Ferry to Butte	12½	5⅛	2	2½	1⅛	3
Shawinigan Falls to Montreal	13½	5	2¾	3	1	—
Niagara Falls to Buffalo *	5¼	6	2	2¾	⅞	1½
Niagara Falls to Buffalo †	7¾	6	2¼	2¾	1½	2½
Chambly to Montreal ‡	7	5	1½	1⅞	—	—
Canon Ferry to Butte §	12⅜	7⅞	2⅛	2½	1⅛	3

* Pins on old line. † Pins on new line. ‡ Approximate dimensions. § Pole top pin.

The following dimensions for standard wooden insulator pins to be used on all transmission lines are proposed in Volume XX. of the transactions of the American Institute of Electrical Engineers. These pins are designed to resist a uniform pull at the smaller end and at right angles to the axis in each case. The length of each pin, in inches, between the shoulder and the threaded end is represented by L, and the diameter of each pin at its shank by D.

L.	D.	L.	D.
1	0.97	9	1.82
2	1.10	10	1.88
3	1.26	11	1.95
4	1.39	13	2.06
5	1.50	15	2.17
6	1.59	17	2.25
7	1.67	19	2.34
8	1.75	21	2.42

The two strongest pins in Table II. appear to be those in use on the line between Shawinigan Falls and Montreal, and on the line from Niagara Falls to Buffalo. The former have a diameter of $2\frac{3}{4}$ inches at the shank, and the wire is carried $16\frac{1}{4}$ inches above the shoulder of the pin. On the new Niagara line the shank diameter of each pin is only $2\frac{1}{4}$ inches, but the line wire is only 10 inches above the shoulder. It was found by tests that a strain of 2100 pounds at the top of the insulator and at right angles to the axis of this Niagara pin was necessary to break it at the shank. This strain is about six times as great as the calculated maximum strain that will occur in service on the line.

Some of the pins here noted are much stronger than those proposed in the above specifications for standard pins. The pins on the old Niagara line have a shank diameter of 2 inches, with a stem only $5\frac{1}{4}$ inches long, while the proposed pin of 2 inches diameter at the shank has a stem 11 inches long. On the Colgate & Oakland line a shank diameter of $2\frac{1}{3}$ inches goes with a length of $10\frac{3}{8}$ inches in the stem, but the proposed pin with this size of shank has a stem 13 inches long. For a shank of $2\frac{1}{4}$ inches diameter the proposed pin has a stem 15 inches long, but the pins with this diameter of shank on the Electra line are only 12 inches long in the stem.

The $2\frac{1}{4}$-inch diameter of shank in the pins on the new Niagara line goes with a length of only $7\frac{3}{4}$ inches in the stem. The new Niagara pin is thus almost exactly twice as strong as the proposed pin, since the strength of a pin where the shank joins the stem varies inversely as the length of the stem, all other factors being the same.

Pins on the Shawinigan Falls line have a shank $2\frac{3}{4}$ inches in diameter, with a length of $13\frac{1}{2}$ inches in the stem; but the largest of the proposed pins, that with a stem 19 inches long, has a diameter of only $2\frac{1}{2}$ inches in the shank.

It is hardly too much to say in the interest of good engineering that the

wooden pin of about 5 inches length of stem and 1½ inches diameter of shank, as well as all longer pins of no greater strength, should be discarded for long transmission lines of high voltage. These pins have done good service on telegraph and telephone lines, and on local lighting circuits of No. 6 B. & S. gauge wire or smaller, and they may well be left for such work.

To meet the conditions of transmission work a change in both the shape and size of pins is necessary. In the first place, the shoulder on pins where the shank and stem meet, that relic of telegraph practice, should be entirely discarded. This change will save considerable lumber on pins of a given diameter at the shank, and will increase the strength of the pin by avoiding the sharp corner at the junction of the shank and stem.

Another change of design should leave an excess of strength in the stem of the pin, to provide for deterioration of the wood, and particularly for charring by current breakage. This increase of diameter and strength near the top of the pin will cost nothing in lumber, for the wood is necessarily there unless it is turned off. The shank of each pin should be proportionately shorter than in the older type, and the pin hole should be bored only part way through the cross-arm. A saving in lumber for pins and for cross-arms will thus be made, since the size of the cross-arm may be less for a given resistance to splitting.

With these changes in general design the pin is a simple cylinder in the shank, with a gentle taper from the shank to form the stem. An example of this design, which might well serve as a basis for a line of standard pins, would be a pin 2 inches in diameter and 3½ inches long in the shank, and tapering for a length of 5 inches from the shank to form the stem with a diameter of 1½ inches at the top. The hole in a cross-arm for this pin should be 3½ inches deep, and this, in an arm 4¾ inches deep, would leave 1¼ inches of wood below the pin. From the lower end of the pin hole, a hole ¼ inch in diameter should run to the bottom of the cross-arm to drain off water. A line of longer pins designed to resist the same line pull as this short one would be strong enough for small conductors, say up to No. 1 B. & S. gauge wire.

For larger wires, long spans and sharp angles in a line, a pin 2¼ inches in diameter and 4½ inches long in the shank, tapering for 5 inches to a diameter of 1¾ inches at the top, or longer pins of equal strength, should be used.

Where the pin holes do not extend through the cross-arm there is no need of a shoulder on the pin to sustain the weight of the line wire. In the cross-arms on the new Niagara Falls line each pin hole is bored to a depth of 5 inches, leaving 1 inch of wood below the hole. On the line from Electra to San Francisco the depth of each pin hole is again 5 inches, and the depth of the cross-arm 6 inches.

The pins for use on the Electra line were kept for several hours in a vat of linseed oil at a temperature of 210 degrees. The pins for the Shawinigan line were boiled in stearic acid. All wooden pins should be treated chemically, but the object of this treatment should be to prevent decay rather than to give them any particular insulating value.

The lack of strength in wooden pins and their destruction in some cases by current leakage is leading to the use of iron and steel pins. Such a pin, in use on the lines of the Washington Power Company, of Spokane, Wash., is made up of a mild steel bar 17½ inches long and 1⅛ inches in diameter, cast into a shank at one end, so that the total length is 18 inches. The cast iron shank has a diameter of 2 1-16 inches, with a shoulder of 2½ inches diameter at its upper end. To prevent the pin from lifting out of its hole a small screw enters the top of the cross-arm and bears on the top end of the shank. Above the cast-iron shank the length of the steel rod is 12 inches, and starting ¾ inch down from its top a portion of the rod ¾ inch long is turned to a diameter of 1 inch. The shoulder thus formed at the top of the pin might serve to hold

a threaded casting thereon, or to secure the insulator with melted sulphur or Portland cement; but it is not stated how the insulators are attached to these pins.

It is said that this pin begins to bend with a pull of 1000 pounds at its top, but that it will support the insulator safely even when badly bent. The large shank of cast iron on this pin was employed because of the fear that a small contact surface between the pin and cross-arm would result in burning the latter by leakage current. It seems, however, that a large wrought iron washer, shrunk onto the steel rod so as to lay on top of the cross-arm, would give enough contact surface and be cheaper than the cast iron shank. The use of a washer instead of the cast iron shank would allow each cross-arm to be reduced 15-16 inch in thickness for the same strength against splitting, and thus make quite a saving of lumber on a long line.

On the network of transmission lines between Spier Falls, Schenectady, Albany and Troy, in the State of New York, the insulators are supported on iron pins of two types. One of these pins, used at corners and where the strain of the line wire is exceptionally heavy, is made up of a wrought iron bolt ¾ inch in diameter and 16½ inches long over the head, and of a malleable iron casting 8¾ inches long. This casting has a flange of 5 by 3¾ inches at its lower end that rests on the top of the cross-arm, and the bolt passes from the top of the casting down through it and the cross-arm. Threads are cut on the lower end of the bolt, and a nut and washer secure it in the cross-arm. The total height of this pin above the cross-arm is 9¼ inches.

For straight work on this line a pin with stem entirely of malleable iron, and a bolt that comes up through the cross-arm and enters the base of the casting, is used. The cast top of this pin has four vertical webs at right angles to each other, and its rectangular base, which rests on the top of the cross-arm, is 3½ by 4 inches. The bolt that comes up through the cross-arm and taps into the base of the casting is ¾ inch in diameter. The cast part of this pin has such a length that the top of its insulator is carried 10¾ inches above the cross-arm. For the casting the length is 9¼ inches.

Both of the types of iron pins in use on the Spier Falls lines are secured to their insulators with Portland cement poured into the pin hole while liquid when the insulator is upside down and the pin is held centrally in its hole. The top of each casting is smaller in diameter than the hole in the insulator, and is grooved so as to hold the cement.

SPECIALISED MACHINE TOOLS

By Joseph Horner

THAT the present is an age of growing specialisation is a generally recognised fact, though its realisation is not always apparent among machine tool builders who do not themselves specialise. The new types of machines are somewhat scattered and rather belittled among the overwhelmingly large numbers of those built after general types by which they are surrounded. Neither are the features which give them a special character always obvious. Some attention may, therefore, be profitably devoted to this subject. Its importance becomes greater from year to year.

At one time there were only two tools in an engineer's, or rather a millwright's, shop,—the lathe and the drill press. There were no planers, or shapers, or slotters, no gear-cutting, milling or grinding machines, no boring machines, no screw machines of any kind, no automatic movements, no machines for flanging or rolling, no power hammers, no moulding machines or power cranes, nothing, in short, except the old lathe of skeleton design and the drill press, such as you may still see in country blacksmith shops.

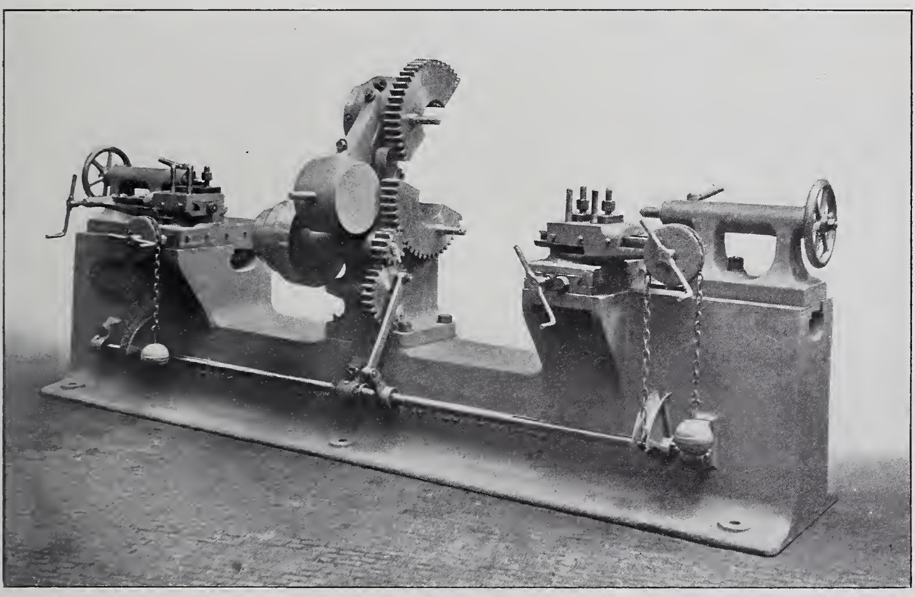
Regarded from this point of view, every modern machine in its first inception was a special tool; but since they are now common, do not rank as such; and the term special is restricted to those smaller groups of tools which are designed for repeated operations of a single character. Thus, one might reckon up about forty distinct classes or groups of lathes, but comparatively few of these are of a strictly special character. Planers, boring machines, drills, and others occur in numerous groups or subdivisions; but most are designed for one great class of general work, and a few only for a particular kind of job, which is the distinction we must observe.

At present the struggle between the general and the special is so severe that a great number of machines are designed to combine the two conditions, such as machines made primarily for the performance of certain functions on the same kind of work, but with adjuncts of which the object is to extend the range of their utility into general practice. Some of these are of eminent value; others cannot be regarded as successful solutions of the problem. In many cases it is not practicable to unite the two sets of requirements in one tool, and when the special is sacrificed in any important degree to the general a mistake is usually made. The exceptions are in those departments where the general work predominates, in which case a special rig-up meets the case.

As a single illustration bearing on this point, take the case of boring. This was originally done in the lathe, or on the drilling machine, the latter being used for the smaller holes, or for work that could not be put in the lathe, and the former for the larger work. It is often done so to-day. In no sense are these makeshift methods when occasional jobs only are in question. But if the work is largely the boring of bearings in cheeks or side frames, it is better to rig up a templet with fixed holes and bore through that, and so avoid separate markings-out and settings. If cylinders are constantly to be bored, then the lathe is not so handy or economical

as the boring machine, in which precise adjustment for height is effected by a rising table, thus avoiding the use of the packings necessary on the lathe saddle.

But the ordinary boring machine is not a special tool, since in shops working on specialities it is superseded by the overhanging cutter of snout type, in which the ordinary bar is dispensed with, the cutter head being made sufficiently rigid to bore truly, though supported from one end only. In more special types the heads are duplicated, while in a few provision is made for milling valve employed, it is still indispensable, and must lie idle, or else without it horizontal boring must be done in a lathe large enough to take such work. An alternative is a horizontal boring bar in a machine, distinct both from a lathe and from a general boring machine, and which is of as special a character as the vertical machine, in having its functions restricted to one kind of duty only, that of boring and facing flanges, as distinct from external turning. What is true of boring operations also holds good of nearly every other operation carried



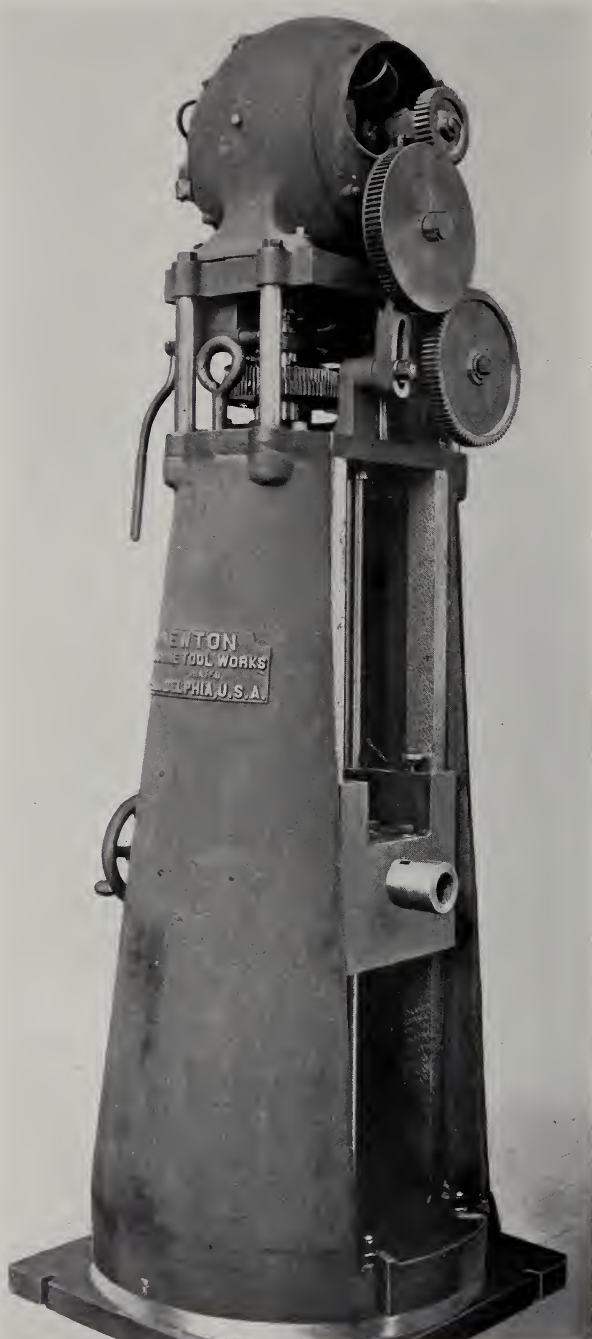
A DOUBLE-AXLE TURNING LATHE. THE HEADSTOCK IS HINGED TO PERMIT EASY REMOVAL AND INSERTION OF AXLES WITHOUT SLIDING THEM IN ENDWISE. MADE BY MESSRS. JOHN HETHERINGTON & SONS, LTD., MANCHESTER, ENGLAND

aces simultaneously with the work of boring, or for boring crankshaft bearings simultaneously with the cylinders.

The foregoing methods are utilised or the smaller classes of cylinders only. Those of large diameters have to be dealt with differently, the bar and cutter head being indispensable. But in these the vertical position of the bar is adopted, and such machines are retained solely for boring large cylinders. Even if there is not enough volume of work in a shop to keep such a machine fully

on in the machine shop and turnery.

A phase of workshop practice which is intimately related to this one of special machine tools is that of jigs and templet making,—related because the one is both the precursor and the successor of the other. Jigs and templets are used to specialise in the work of the general machine. Thus, a drilling templet, more or less elaborate, is made to fix the centres of holes to be produced by a common drilling machine. It would not pay to make such a templet



A PORTABLE DRILLING AND BORING STANDARD MADE BY THE NEWTON MACHINE TOOL WORKS, PHILADELPHIA. THE ELECTRIC MOTOR WAS SUPPLIED BY THE GENERAL ELECTRIC CO., SCHENECTADY, N. Y.

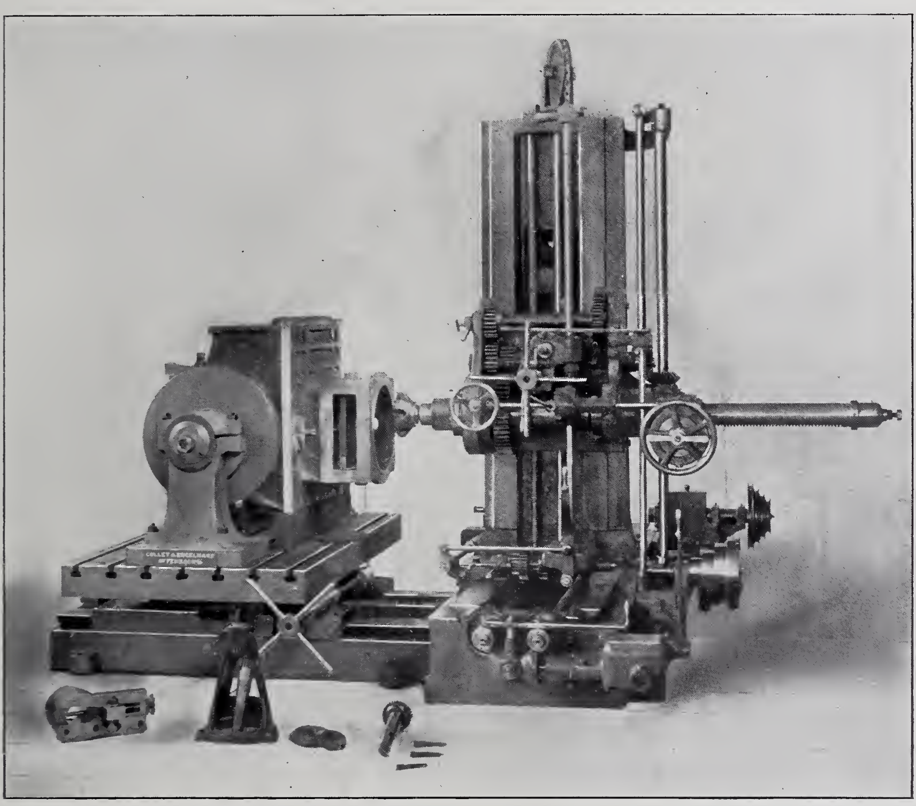
for a few pieces of similar work. Neither would it pay to drill a large number of pieces without an aid of this kind. Just when its expense is justifiable or necessary is a matter of judgment, and of estimating relative cost as well as of uniformity and accuracy of results. Such a templet may in some cases be made most elaborately, completely encasing its work, and containing provision for facing, tapping, counterboring, etc., in which case it is generally termed a jig.

If the piece of work for which such a jig is designed has to be made constantly, year by year, without alteration, the jig may give place to a machine in which the jig is placed in a permanent form. Instead of one, or, perhaps, two or three drill spindles guided by holes in the detached jig, there may be a dozen or more, having the centres of their spindles unalterably fixed in a machine, and operating in the same or in different planes horizontally and vertically. In this case the machine embodies the highest specialisation possible.

There is not much hesitation as to the policy of constructing a highly specialised machine, unless for any other kind of work than that for which it is designed, when the dimensions and weight are moderate and the details not very intricate. But when it becomes very massive and

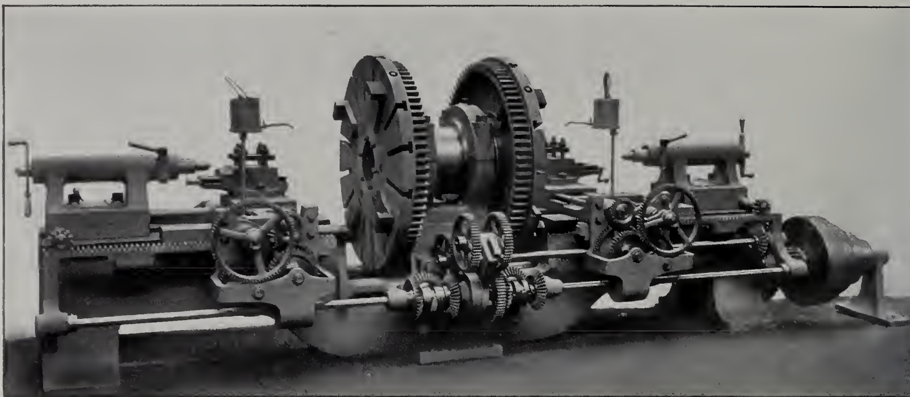
intricate, the policy requires very careful consideration. Hence, the big, very special machines and the complicated, smaller ones are confined to comparatively few shops. Small boiler shops, for example, cannot afford the luxury of boiler-shell drilling machines; but they must, perforce, drill plates separately, and ream by hand holes that do not come quite fair. Heavy flanging machines are also prohibitive, and heavy work must then be either hand-flanged or sublet to others specially equipped for it.

Many firms cannot afford a bevel-wheel cutting machine, or a worm-wheel hobbing machine, but must do these classes of work on a universal milling machine, or else put them out to be done. Automatics, too, are luxuries that require a lot of work to keep them fully employed, and few small shops can afford them. Herein lies one explanation of the growing number of firms who work for the trade, as in gear cutting, in boiler flanging, stud and screw making, turret work, machine moulding, etc. To some extent this has always been done, but never so extensively as at present. And, concurrently, there is the fact that many firms now lay down special machines for certain departments of their business who would not have entertained the idea of doing so a few years ago, all of which testifies to specialised growth and to the severity of competition.



A MACHINE FOR BORING AND MILLING LOCOMOTIVE CYLINDERS. MADE BY MESSRS. COLLET & ENGELHARD, OFFENBACH-ON-THE-MAIN, GERMANY

Every new industry of magnitude gives birth to new designs of machines. First, manufacturers try to get along



DOUBLE WHEEL AND TIRE LATHE MADE BY MESSRS. JOHN HETHERINGTON & SONS, LTD., MANCHESTER, ENGLAND

with the old ones, making jigs and templets, and generally following the old methods. Then modifications are made in details, giving elementary forms of combination machines, and at last new designs are evolved, in which makeshifts are wholly abandoned in favour of mechanisms designed for the performance of only one class of work. There must, of course, be a sufficient volume of work to pay for new machinery; but, given that condition, there seems no limit in reason to the developments that may arise from a new industry.

We have seen these changes during recent years in armour plate manufacture, in the supersession of iron by steel, in the cycle trade, and in the electrical and motor-car industries, each of which is responsible for a number of new tools. Some of these in a short time become appropriated by the general engineer, and another generation will not be aware of the source of their evolution.

A result of these changes is that the manufacture of machine tools has become highly specialised. Though but one department of engineers' work, it is now cut up into a number of distinct industries. Already some of those subdivisions are also being broken up. Lathes of all kinds, for example, are no longer made by one firm. Those who make turret lathes seldom make wheel lathes or axle lathes. Vertical lathes are a sole specialty in the business of some few firms. Spinning lathes are generally the product of those who manufacture machines for sheet-metal workers. Copying lathes form a department of woodworking machinery. This last-named industry is one that stands quite apart from general engineering, as it also does from machine-tool making. Yet several hundred firms are engaged regularly in this line. Metal-planing machines are taken in hand by a few firms, portable machines by others, and a large number of other examples of specialisation in tool manufacture might be instanced.

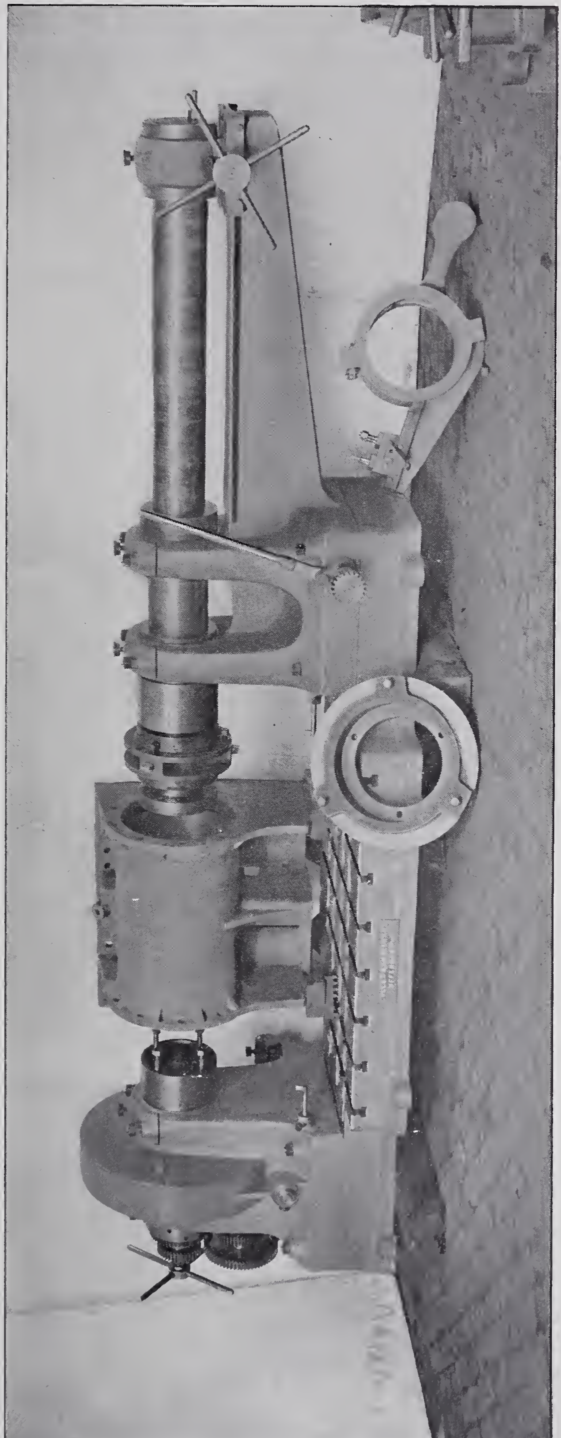
A few ways in which machine tools are highly specialised may be noted here. An example in lathes is one for turning and grinding tramway wheels on their axles. It is not like the railway-wheel lathe, though its duties are similar, tram wheels being smaller than railway wheels. The bed has two fixed gaps to receive the wheels, and two saddles on which slide rests and grinding wheels are interchangeable. The driving is from an ordinary type of back-geared lathe head and back shaft. The grinding wheels have their own countershaft.

A special type of shaft-turning lathe is that which carries two sets of headstocks, which, therefore, form two independent lathes on one bed. When one set is removed, the lathe will turn shafts

80 feet or more in length, or cut screws of that length. Each saddle carries three or four tools, and all can operate simultaneously. Special sets of pulleys at the ends of the bed impart a quick-return motion to the saddles by power, an important detail when the great length of bed is considered.

A valuable class of lathes, which, though special, are more common than formerly, is the movable gap type. The ordinary fixed gap, cast in the bed, is, as someone has humourously put it, "1-16 inch too short for a lot of jobs." Yet a wide gap is inconsistent with turning up close to the face plate. A movable gap is produced by separating the bed from the base plate, and making the first capable of longitudinal adjustment on the second. The movable bed carries the rest and the loose poppet. The connection between the headstock gears and the lead screw or the feed rod is made from within the base plate, where a long rod transmits motion through a sliding spur gear to a similar gear on a shaft within the movable bed. This is a style of lathe which is free from the usual objections made to the ordinary gap lathe, and it meets all requirements.

Not many have heard of driving work between centres from the tailstock end, yet this is done in one design of lathe to save changing shafts end for end. A long shaft, carrying a pinion driven from the toothed wheel on the live spindle, runs through the length of the bed. It carries a pinion also at the farther end, gearing with a driver wheel of the same size as that on the headstock. This wheel en-



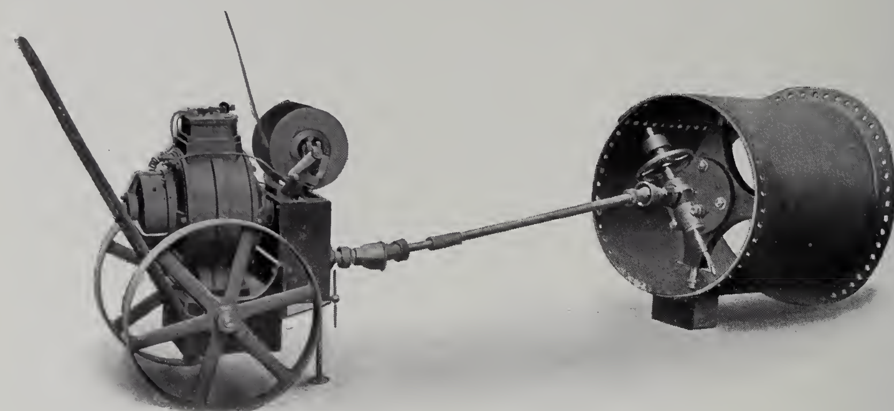
A LOCOMOTIVE CYLINDER BORING MACHINE MADE BY MESSRS. COLLETT & ENGELHARD, OFFENBACH-ON-THE-MAIN, GERMANY

circles the body of the tailstock in order not to interfere with its spindle, and the shaft is driven from this, the carrier being shifted to allow the end of the shaft next the headstock to be finished.

From a very simple affair the centering machine, the adjunct of the lathe, has developed into special forms. At one time the only centering done was by hand, with centre punch, or fiddle-drill, and countersink. Then came very plain "centering lathes," followed by machines containing provisions for cutting off square as well as centering, and then by others with devices for accelerating the rate of rotation as the tool was fed from circumference to centre. Finally came double-ended machines for treating both ends of axles and shafts simultaneously, when a sufficient number of pieces warrant the design.

The vertical boring machine, used chiefly or entirely as a lathe for boring, has become a familiar object in shops doing repetition work. Rigged up with a boring-bar and loose cutters, and a three or four-jaw chuck, it is a great advance on the horizontal lathe when occupied in doing boring and turning. The various arrangements of cutters afford an interesting study in boring bars and in reamers, one of the chief variations being in the expanding types of cutters and minute adjustments provided for taking up wear.

In other ways the vertical boring mill has been a very adaptable tool. The extension device and the bar for slotting are both adjuncts of great utility. To be able to move the uprights back to increase the capacity of the machine by 50 per cent. is a great feature, as is also the ability to slot a keyway or other recess in a wheel or pulley without resetting on another machine.



A PORTABLE ELECTRIC DRILLING MACHINE MADE BY EMIL CAPITAINE & CO., FRANKFORT-ON-THE-MAIN, GERMANY

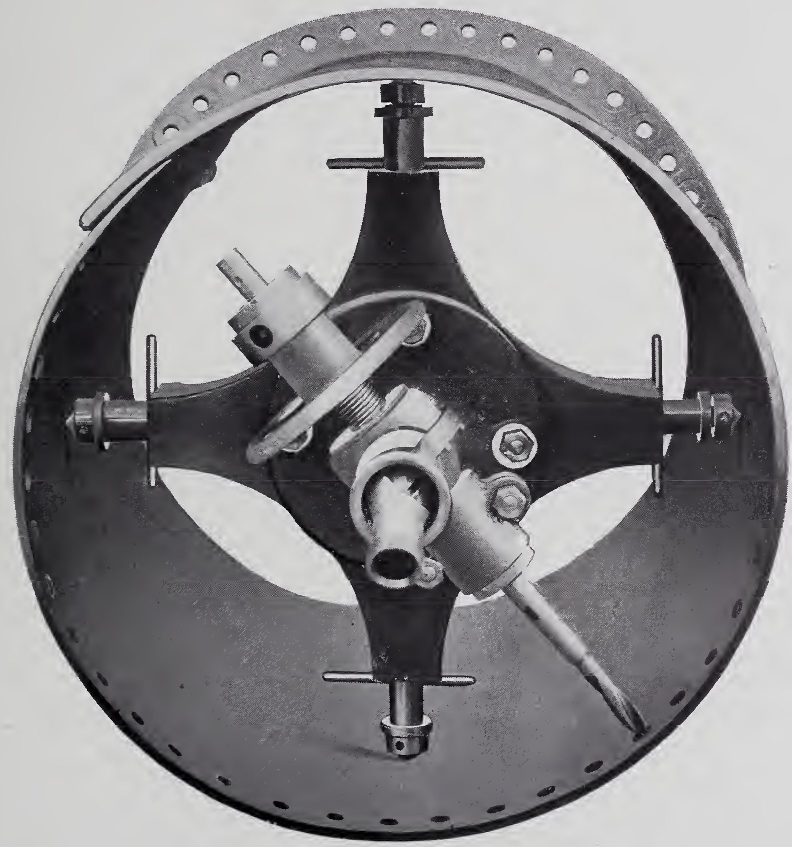
Turning to planing machines, these become highly specialised when used for other functions besides planing horizontal and vertical faces. When a firm spends £600 to £800 or more on a big planer, the desire is natural to have it capable of performing something more than the two regular operations. The increasing complexity and mass of castings now made renders this desirable, because resetting such masses on other machines often becomes a big job, which it is desirable to avoid.

One of the improvements in big planers lies in making provision for the planing of ends without shifting the work after the top and sides have been done. In such a case a tool box is made to move on the cross rail by its own separate set of three pulleys, screw tappets or stops being set on a bar above the cross rail to adjust the length of stroke.

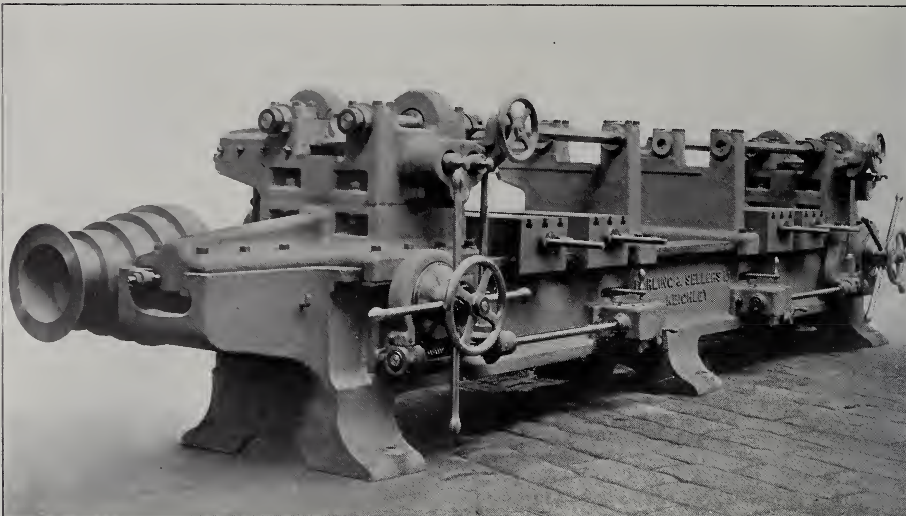
One end can be planed thus, and should another have to be faced, resetting is necessary.

Another job, which it is often desirable to do on a planer, is boring, and more machines ought to be fitted with an adjunct for this purpose. There are few forgings or castings that do not require drilling and boring, work which must in most cases be transferred to other machines. In the case of large pieces, these either go to the radial drills or to the base plates on drilling, boring and tapping machines. But much of it might be done without the trouble of shifting if a boring head were fitted to the cross rail of a planing machine, as is done in some few cases. The objection to this practice is that the machine lies idle for planing while the drill is in operation, but this is more than compensated for by the saving of time in resetting.

The open-side planing machine, built in a design which is really a variant from the common machine, is a growing favourite, one vertical housing being abandoned, leaving that side open for the insertion of broad work. There is, therefore, one housing and one cross slide, reaching over the table, the proportions being modified accordingly. The single housing takes the form of a stiff standard, having broad sliding faces for the cross slide, or tool arm, which is very broad on the face on which it slides on the standard, and goes off in a semi-parabolic form towards the unsupported



ANOTHER VIEW OF THE CAPITAINE DRILL



A QUADRUPLE HORIZONTAL BORING MACHINE MADE BY MESSRS. DARLING & SELLERS, LTD., KEIGHLEY

end. In this way spring is eliminated.

The open-side milling machine is as useful in its line as the open-side planer, and as varied in form. In one design of this class a long bed has a sliding carriage with a circular, slotted table. The arm is carried on a standard bolted to one side of the bed, and the carriage is adjusted along a vertical face of the arm. This, with the movement of the table on the bed below, gives a large range of diameters and widths.

In a few special cases planers are fitted with multiple tool holders for operating on a number of pieces at a time. In one case the writer has seen about a dozen tools at work planing branch flanges for pipes. A similar device is adopted for planing large nuts in quantity, and for the flats on gun barrels, for example.

The pit planing machine, in which the standards travel and carry the cross rail over the work, bolted stationary in a pit beneath, is a design that appears to be growing on the Continent of Europe.

The same idea is embodied in some milling machines for operating on locomotive frame plates, boiler plates, etc. The housings may travel along the ways when required, and they carry the cross rail between them, the work being bolted down in the pit. In one design of this kind the machine is made double-headed, and four milling spindles can be operated at once.

The face-milling or "ending" machines are no longer special tools, but the great group includes many special sub-types. A ring of cutters is adaptable to face or edge milling on many kinds of work. All that is necessary is to arrange the relative movements of the work-slides and the cutter to suit the job and to drive suitably.

The idea of a vertical shaper has been borrowed from the vertical planer. The two possess certain resemblances, as in the vertical pillar and the horizontal bed and tables. The essential difference lies in the direction of the cut, which is horizontal in the shaper, with a true shaper arm. The tool box can be swivelled, so that vertical or horizontal or angular faces can be cut. The same type is made portable, being then without the bed and tables.

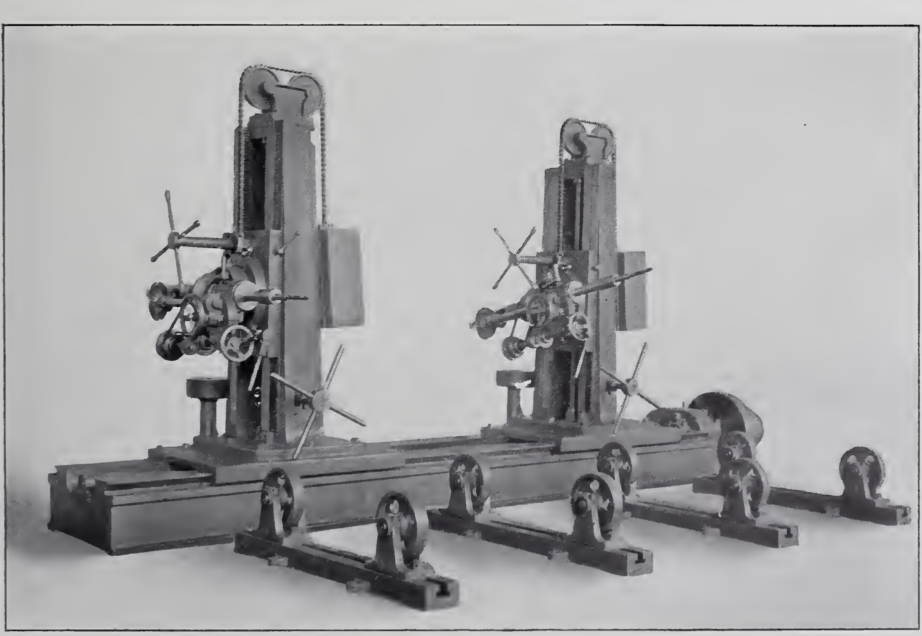
In a shaping machine for locomotive cylinders specially, the arm is driven with a spiral pinion and rack. The arm stands high, the table low, and the latter is circular on a sliding carriage moving on a short bed.

Armour-plate work has occasioned the development of some big specialised machines,—outside of the hydraulic presses,—notably the slotters, which assume different forms from those of the standard types. The edges of these plates are tooled most conveniently by slotting, and as few edges stand square, the slotting arm has provision for setting and working at an angle as well as perpendicularly.

Machines for facing pipe flanges are laid down only where pipes are made in quantity. In some of these the two facing heads are placed at the ends of a bed, along which they can be racked to suit pipes of varying lengths. The mandrels are driven by a stepped cone pulley, through a long shaft within the bed, driving spur gears. Each mandrel carries a facing arm with two independent tool slides, star feed for self-acting traverse, two tools cutting on each flange simultaneously. A bracket is bolted to one side of the machine, to be used when elbows have to be faced. The pipe-holding stays are an important part of such a machine. These are fitted with caps that are thrown back readily or lifted off, and receive packing blocks to suit various sizes of pipes. In some cases the pipe is carried in vee blocks, adjustment of which is effected by sliding them along base plates, two vees being used on each base plate. Their lateral movements at right angles with the lathe axis raises or lowers the work.

The numerous designs of multiple drills testify to their growing specialisation. These machines are too common now to be considered very special, and yet the fact of adjustability of the spindles separates them from strictly standard types. Made both in vertical and horizontal designs, and to drill circles or other geometrical forms of holes, they have filled a place that was long unoccupied. These machines are a boon to the maker of cocks and valves, of pipes and columns, to templet makers, in railway shops, and others where quantities of hole drilling to fixed and variable centres is required. Several of the horizontal machines are made double-ended to operate on two flanges at one time.

There is a type of radial drilling ma-



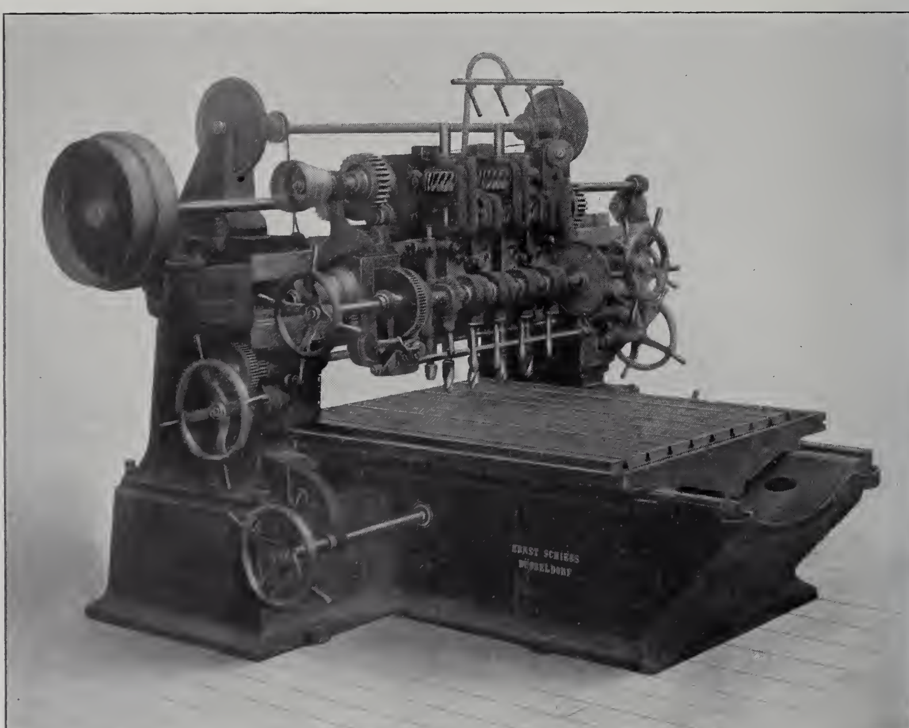
A DOUBLE BOILER SHELL DRILLING MACHINE MADE BY THE SOCIÉTÉ ALSACIENNE DE CONSTRUCTIONS MECANIQUES, GRAFENSTADEN

chine, not largely represented, but which is valuable by reason of the universality of its movements. The radial arm has a circular base which is adjustable around a face on the carriage that slides vertically upon the pillar. It is retained by bolts in a circular tee groove, and is rotated by worm gear. The drilling spindle also rotates on the face of its carriage, on the radial arm, so that vertical and horizontal angles are completely provided for. In another design the arm has a movement of 30 degrees only over a quadrant plate, a range which covers most requirements.

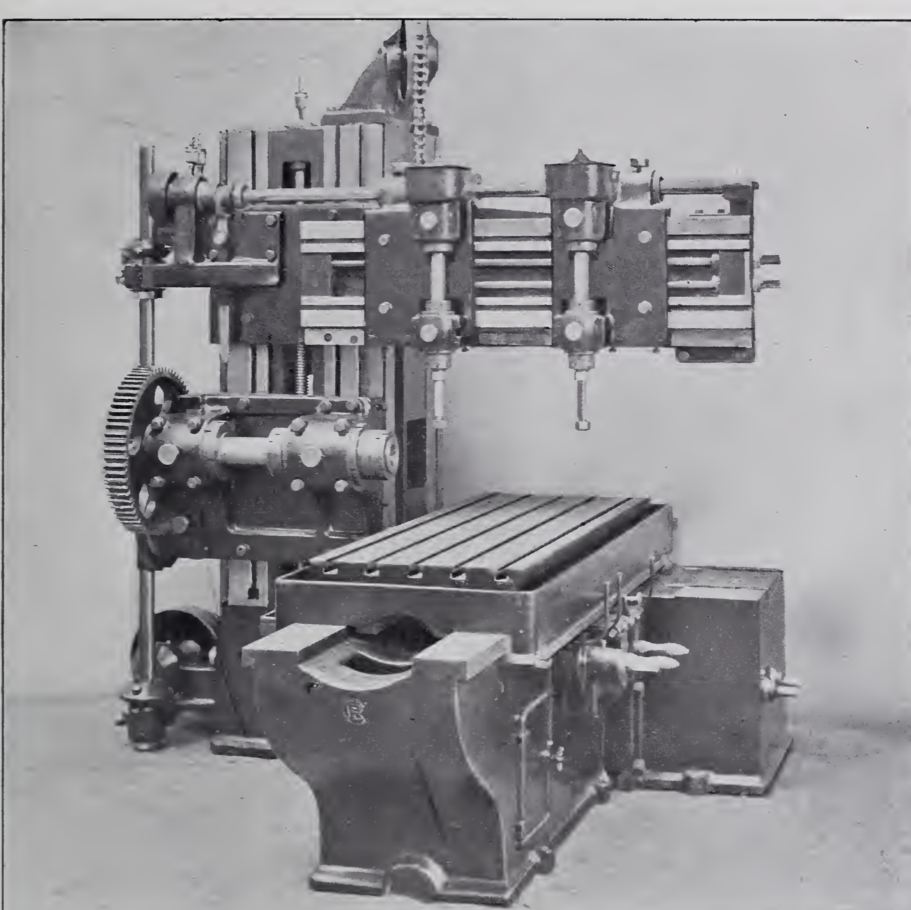
In one form of universal radial drill, in which the arm is adjustable bodily in the horizontal direction, the head is pivoted between two cheeks which form the arm, giving a range of angle in one vertical plane. The angle in a vertical plane at right angles with the first is obtained by swivelling the spindle on a circular face on the head. In this way drilling can be done anywhere between the vertical and horizontal, and at straightforward and side angles.

A universal radial boring machine mounted on a central pillar has advantages, one of which is that the overhang of the arm in the usual form is lessened. The pillar is independent, that is, its broad base can be bolted down to the floor where most convenient. The arm is adjustable vertically upon the pillar, and horizontally in relation to it; but the drilling head, as such, does not traverse radially, being attached to one end of the arm, and moving with it. It has circular adjustment in a vertical plane on the end of the arm. The latter is turned radially by worm gear on the base.

There is one radial machine of universal type, fitted with six spindles in line, operated by spiral gears, in which the whole affair is carried on a bed along which the standard can be moved and



A MULTIPLE-SPINDLE LOCOMOTIVE TUBE-PLATE DRILLING MACHINE MADE BY ERNST SCHIESS, DUESSELDORF

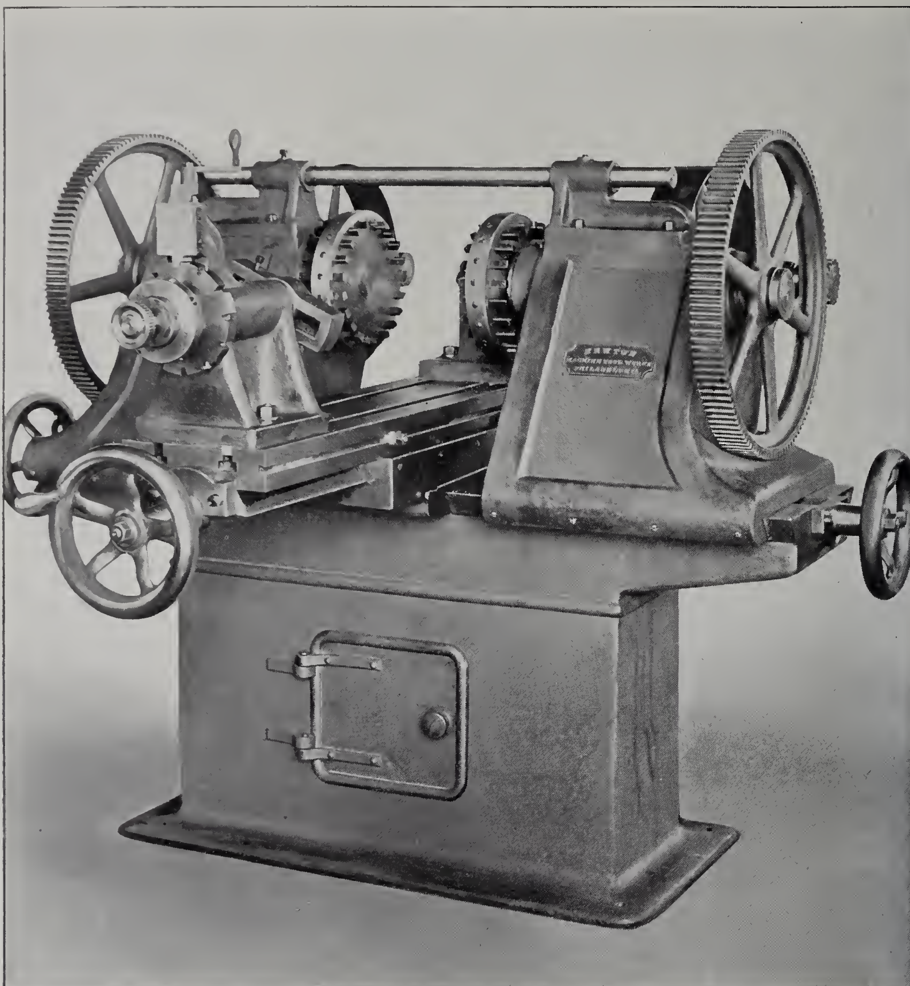


A THREE-SPINDLE SLAB MILLING MACHINE MADE BY J. E. REINECKER, CHEMNITZ-GABLENZ, GERMANY
TWO OF THE SPINDLES ARE VERTICAL AND ONE IS HORIZONTAL

adjusted by power or by hand. The radial arm is moved horizontally in a sleeve on top of the standard. At the outer end of the arm is fitted the head, which carries the bearings for the drill spindles. The beam can be swung around its head in a complete circle in the horizontal plane, and adjusted bodily, in the vertical direction. The spindles are adjustable along the beam, with arrangements for spacing, and each is adjustable independently of the others, both in horizontal and vertical positions. They are counterbalanced and fitted with both hand and power feeds.

A special drilling machine has been evolved for bridge-builders for drilling both ends of eye bars at once. Two heads slide on a bed, being adjustable thereon for centres, and they are connected with steel bars which have the same expansion as the links to be drilled, so that uniformity of centres is assured.

In a rather large class of drilling machines the work is carried at the side of the machine, either on a bedplate or a stand, or on trolleys. Apparently these models have been derived from the horizontal drilling, boring, and tapping machines, which they resemble in some respects. The work is either traversed past the fixed drills from hole to hole or bolted down, and the drilling pillar is adjusted to suit the successive holes.



A DOUBLE-HEAD MILLING MACHINE, WITH CENTRES FOR HOLDING RODS TO MILL THEIR ENDS. MADE BY THE NEWTON MACHINE TOOL WORKS, PHILADELPHIA

These machines mostly have horizontal spindles, but in a few cases they are vertical, and in one, double-ended, so permitting of two sets of holes to be drilled at one time.

The multiple spindle machine has its limitations. It is at its best in drills, a form of tool to which it is admirably adapted, and to which there is hardly a limit in the number which can be employed. In boring and milling machines several spindles can be used with advantage, and with capacity for adjustments. Few lathes are made in this way, though the advantages of being able to turn three or four shafts or to cut as many screw threads simultaneously should be favourable to their use. But the retention of accuracy, and even economical working, seems to be best secured by the use of separate lathes, three or four of which can be attended to by one man and a boy, doing perfectly straightforward work.

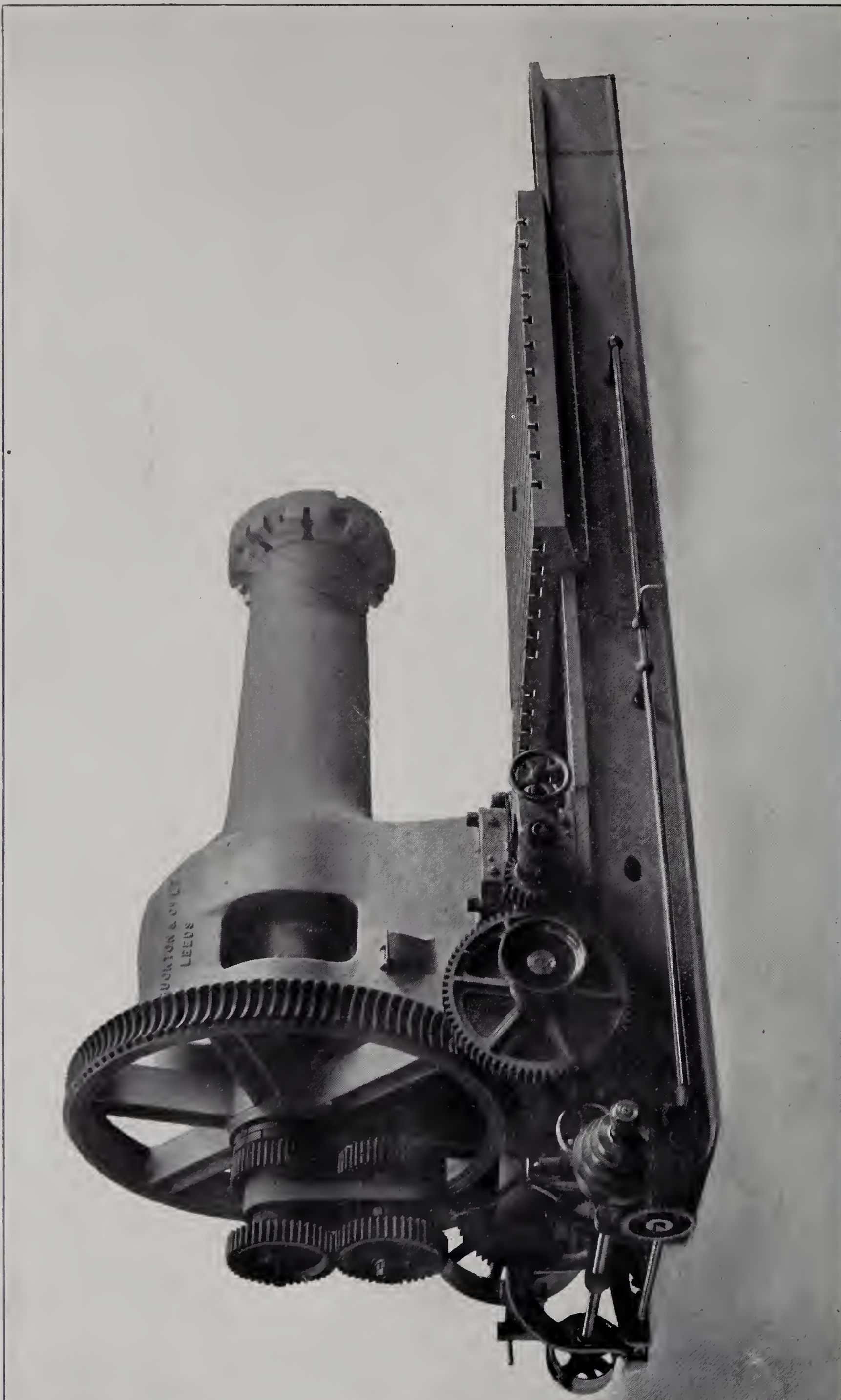
Gear cutting is responsible for a number of very highly specialised machines, including several for the generation of tooth profiles. Worm hobbing ma-

chines have sprung into greater prominence, and the necessity for their use more imperative, in consequence of the demands made by the electric drive for smooth reduction gear. Nothing is better than a good worm gear, and such can only be made truly by cutting with a hob, hence the occasion for the growth of the machines in question. In a perfect design the wheel blank must be driven independently of the hob, and at a speed harmonising with that of the latter. Provision must also be made for regulating the depth of cut.

The cutter forming and grinding machines may legitimately be classed among special tools. The interesting feature which they have in common is that the form principle is adopted to produce cutters of any desired profiles, the shapes being obtained directly from the form piece. The cutter spindle is movable around a universal joint, situated at the end opposite to the wheel, and is thus adaptable to the contour of the form, on which it is pressed by a lever in the hand of the attendant. The spindle is fitted in bearings coned to take up wear, and these are enclosed in a long tube.

Cold iron saws are made in more adaptable designs than of old. In some cases where they are worm-driven the worm and wheel are enclosed in a bath of oil, the worm being on the driving shaft, the wheel on the saw spindle. Another improvement consists in provision for angular sawing, the spindle being capable of adjustment by a graduated scale. Another is the substitution of a milling disc for facing, in addition to the saw, so enabling the machine to be used for both kinds of operations, which is a great convenience in the cutting of steel sections to exact length and finish. And these machines are also increasing in dimensions until that stage is reached in which the spindle is made to accommodate itself to work too massive to be moved. The spindle carriage then slides vertically on a standard, its mass being counterbalanced, while the saw can also be set at any angle from vertical to horizontal. There is a special design of cold saw in which the teeth are kept sharpened automatically while cutting. In the same machine the speed of the bar being cut and the feed of the saw are automatically increased from circumference to centre. Even the humble hack saw is becoming subjected to considerable specialisation, being made vertical in action and duplicated in one framing, and also suitable for an increasingly large class of work. The advantage of the vertical over the horizontal design is that less floor space is occupied, and that the chips fall away from the cut.

The design of special tools must ever be regarded from the practical point of view. Here, as in other matters, the law of supply and demand holds good. Many ingenious designs, patented and otherwise, have not caught on, either because the demand for such was limited, or because, on the whole, they have not offered sufficient advantages to justify the displacement by them of existing tools. Few designs have been more successful or more largely copied than the open spindle of the capstan lathe, the great convenience of which in the insertion of work with heads cannot be exaggerated. In every turnery lathes fitted thus fill an essential place. But designs more ingenious than this have fallen flat, and are seldom asked for, such, for example, as square hole drilling machines, or propellor blade planers, and others that might be mentioned, having a very limited use. Ingenuity of design alone is not the key to success. To be successful, either a machine must be absolutely indispensable, in the sense that only by its employment can certain necessary operations be performed, or else it must be economically preferable to those which it displaces. An example of the first named would be furnished by a bevel-gear cutter operating by planing; examples of the second occur in numerous portable machines for drilling, tapping, chipping, caulking, etc., which either save hand work or awkward handling of heavy work. Another notable example of this kind is furnished by the key seaters. Only a few years since all key grooving went to the slotter, the



A SNOUT BORING MACHINE WHICH WILL BORE A BLIND-END CYLINDER. MADE BY MESSRS. JOSHUA BUCKTON & CO., LTD., LEEDS, ENGLAND

slot drill, the planing and the milling machine, and some was done by hand. When Mr. Knowles showed the way to cut a key groove with a serrated tool he supplied a badly wanted requirement in the machine shops. Others followed, and key-seating machines are now the leading specialty of several firms.

New designs do not embody new principles. The forty or fifty distinct types of lathes in use had their progenitor in the old bar lathe of Maudslay. In all the planing machines, shapers and slotters the changes are but rung on the first rectilinear cutting machines of Murray and Roberts. From this point of view we might discern in modern machines embodiments in combination of the machine tool and the jig, until one can hardly say where the jig becomes merged in the machine. Though the elements of machine tools are simple, and though the same things occur in diverse forms, they are modified so greatly and are so intertwined that an analysis of them into their primitive elements becomes an engrossing study.

DEVELOPING A WATER-POWER

ELEMENTS OF FINANCIAL AND COMMERCIAL SUCCESS

By Thorburn Reid

SEVERAL years ago the writer was retained by a small municipality to investigate the feasibility of transmitting electrically the energy of a small water-power a distance of 16 miles for the purpose of lighting the town and furnishing power during the day for factories. It was reported that 400 horse-power were available, that much work had already been done towards developing the power, including the building of a canal 10 feet deep, 30 feet wide, and about 3000 feet long, and that all this property could be bought at a figure lower than the cost of the work already done.

Careful investigation showed that scarcely a single factor of commercial success was present. The power had been enormously overrated, and was very variable; the cost of development was very high; and there was practically no market for the power in the immediate vicinity.

On one side of the canal spread a low plateau, about a mile square, with perhaps half a dozen small houses scattered about. Faintly outlined by pine stakes, could be seen the lines of streets and avenues covering the whole plateau, and on one of these avenues, almost hidden by the thick grass, appeared the rotting ties and rusty rails of what had evidently once been a street railway. The canal had been well made, and was probably of sufficient capacity to supply from six to eight hundred horse-power. About midway of its length were the remains of a timber bulkhead and overflow gate. At its lower end the forebay bulkhead and gate with the timber foundations for the turbines were still in good condition, and the solid stone walls of the power house foundation were a foot or so above the grass and blackberry bushes clinging to their sides.

In a barn near by, were unearthed, from under the hay in the loft, the turbine shafts, steel casings, bearings, and gear wheels. The water-power property, including the canal, the timber work, power house and machinery, and several acres of land between the canal and the river, were offered for sale at a price that must have been considerably less than the cost of labour and material. The whole was a melancholy example of misdirected energy and useless ex-

penditure, and was typical of many similar cases that come to light from time to time.

The power had been originally estimated at 800 horse-power, but when first brought to the writer's attention the estimate had been reduced to 400 horse-power. After a careful study of the situation and investigation of all the records available, the writer reported that by means of the slight additional head and the storage of water afforded by the construction of a low dam across the river at the head of the canal, 175 horse-power could be counted on for the few hours each day when the load would be heaviest, that being the limit of the power to be expected during low stages of the river. Here, then, was a clear example of over-estimation of power available, excessive cost of development and operation, and an almost complete lack of market for the power when developed.

In its final analysis the object sought in the development and utilisation of any water-power is a reasonable profit on the investment required. Simple and obvious as this proposition may appear, it is, nevertheless, very often lost sight of or obscured by the multitude of details that must be considered in the preliminary investigations, and the engineer generally finds it just as necessary to direct his client's attention to this fundamental requirement as to insist on the inclusion in the investigation of every factor that may affect the object sought.

For convenience, these factors may be classed in three divisions:—first, investment required; second, operating expenses; third, income.

INVESTMENT REQUIRED

The sources of expense properly chargeable to the investment account are:—

1.—Preliminary investigations.

2.—Promoting and organizing.

3.—The necessary real estate and water rights.

4.—Franchise and rights of way for pole lines, etc.

5.—Hydraulic work, such as the dam, canal, etc., the power plant, transmission line, substations and distributing system. Under this head should be included the engineer's fee for designing and supervising the plant, and the salaries of any officers who may be receiving pay during the constructional stage.

6.—Interest on all money expended during the preliminary and constructional stage, or until the plant has been completed and is delivering power to customers.

During the subsequent history of the plant questions often arise as to whether certain disbursements for additions or improvements should properly be charged to investment or to operating expense. So varied are the considerations affecting such disbursements that no general rule can be formulated that will automatically relegate each to its proper account; but the general principle may be laid down that no expenditure is properly chargeable to investment account that does not increase proportionally the net profit derived from the plant either by increasing the income or decreasing the operating cost.

Indeed, unless this condition is satisfied, such expenditure should not be incurred unless some unforeseen contingency makes it necessary in order to prevent a reduction in the net profit. In such cases entirely extraneous considerations, such as the form of the company's securities or the effect on the market of these securities, may decide to which account the expenditures should be charged. That is, charging to capital account may mean a permanent reduction in the dividend rate, while charging to operating cost might mean a temporary reduction, with a subsequent return to the full dividend rate.

A well-managed company, however, should accumulate a surplus which would be applicable to such unforeseen expenditures, thus preventing a disturbance of the dividend rate. Such surplus should be charged to operating expenses, and will be considered more in detail under that head.

It is not possible in this article to go into the details of the items constituting

investment expenditure, but a few general rules may be stated.

First. It is scarcely possible in the preliminary report to work out the cost in too great detail. The engineer is often tempted to guess at the smaller items of cost or to cover his laxity by a large allowance for "contingencies," alleging the changing prices of material and labour as an excuse for inaccuracy. The item of "contingencies" is expected to cover some unforeseen rise in the price of material or labour, the failure of a contractor, or the necessity for some extra expenditure due to unusual conditions developed only after the work was started, but not to cover any expenditure that could have been foreseen and allowed for by the engineer before the work was commenced. Even with the most painstaking and detailed estimate the actual cost shows a strong tendency to exceed it, so much so that most engineers with experience in such enterprises make a liberal allowance over and above their first estimate.

Second. Cheap material and labour are fatal to success. They are the prolific source of stoppages and breakdowns, and the consequent expenditure for repairs and the loss of income will often use up in one year the whole saving in the cost of cheap material over that of the very best which the market may have afforded.

Third. Aside from the engineer's allowance for unforeseen contingencies during construction, ample allowance should be made for carrying the enterprise along until income from the sale of light and power shall equal or exceed the operating expenses. Even though the demand in the territory to be supplied may far exceed the capacity of the plant, it takes time, nevertheless, to educate customers, and time for them to obtain necessary apparatus and make the changes required before they can be connected in, and during this building-up period operating expenses will be nearly if not quite as high as when the plant is running at its full capacity.

Fourth. The warning against overrating the amount of power available cannot be repeated too often or emphasised too much. Such power overrating is an almost universal error, and even the most conservative of engineers is liable to make it at times. A single measurement of the stream flow or a number of isolated measurements are valueless, no matter how positive the natives may be that the stream at the time is as low as it ever becomes. Their untrained observation has time and time again proved to be worthless, and nothing less than a series of gauge measurements extending over a series of years and supplemented by accurate flow measurements at low stages of the stream ought to be trusted, if anything like accuracy be required.

Calculations based on the drainage area alone are nearly always unreliable. The minimum power to be obtained from a stream is not based on the average amount of water it discharges, as si evidenced by the fact that some streams with considerable drainage area run entirely dry at times. Of course, where sufficient reservoir capacity can be obtained to store up the water and discharge it at somewhere near the average flow of the stream the year round, calculation of the drainage area and run-off becomes of value, but such cases are rare. Many engineers still continue, apparently from force of habit or with a blind following of precedent, to incorporate in their reports elaborate investigations of drainage area, precipitation, and run-off, when, in fact, the power available at the lowest stage of the stream is the important point to be decided. Such investigations are rarely worth the time required to make the calculations involved.

Unless, then, the stream under consideration has been systematically measured and gauged for a long period, its minimum power can only be guessed. The conservative engineer will divide the lowest guess by two, and, if he has had much experience, will feel a little doubtful even then.

Fifth. Floods will often reduce the output of the plant far below its normal capacity, and may cause it even to be shut down entirely. Such stoppages are nearly always disastrous to the prof-

itable operation of the plant, and unless some means can be provided to conserve the effective head on the water-wheels at such times, some auxiliary source of power, such as steam or gas engines, must be kept in reserve. To most people it seems a great waste of money to tie it up in machinery that will be productive for, perhaps, not more than two or three weeks a year; but where uncontrollable floods are inevitable and a shut-down of the plant is not feasible, such expenditure must be made, and should be considered as proper part of the cost of development The first cost of this auxiliary plant may be much reduced by disregarding high fuel economy. This is warranted by its short term of operation, since the saving in interest on first cost and other fixed charges will usually far overbalance the cost of the excess fuel consumed during its restricted period of operation.

OPERATING EXPENSES

The operating expenses of a water-power plant are very nearly constant, no matter what may be the ratio of output to capacity. Certain expenses, such as interest, insurance, taxes, and depreciation, are constant in any kind of power plant. The other items of expense,—repairs, labour and supplies,—vary somewhat with changes in the output; but the variation in these items is much greater in a steam plant than in a water-power plant. In addition to this, in a steam plant, or any plant obtaining its power from the consumption of fuel, the fuel cost, which amounts, roughly, to one-third the total operating cost, will vary nearly in proportion to the output. The operating cost of a water-power plant per horse-power will, therefore, vary very nearly inversely with the output, while in a steam plant it decreases much more slowly than the output increases. The importance of a market for the full capacity of the water-power plant is thus made apparent.

The operating cost of a steam-power plant includes all the items required by a water-power plant and adds to these the cost of fuel. In a water-power plant the item corresponding to cost of fuel could be called "cost of water," a practically constant quantity, being interest, insurance, taxes, depreciation, repairs and supplies for that part of the plant which serves to bring the water under pressure to the water-wheels and to carry it away from them after it has done its work. The so-called fixed charges,—interest, insurance, depreciation and taxes,—are practically dependent on the first cost of the plant. The other charges are labour, repairs, supplies, and administration expenses.

As to labour, the most important requisite is to pay sufficiently high wages and salaries to secure first-class men in positions of responsibility. A competent chief engineer will usually save each year many times the difference between his pay and that of an inferior man. Each breakdown due to carelessness, ignorance or incompetence means, besides the cost of repairs and the loss of income, an impairment of public confidence, which will do more to imperil the financial success of the plant than almost anything else that can happen to it. In small plants of a few hundred horse-power capacity the question of how much the company can afford to pay for a chief engineer is a difficult one to decide, but in general it is better economy in the end to pay more rather than less than at first may seem advisable. In large plants, running up into thousands of horse-power, the main difficulty is usually to find a man good enough for the place at any price.

After the heads of departments have been secured, the responsibility of hiring their subordinates and of operating the plant should be laid firmly upon their shoulders, and they should then be judged entirely by results. Interference by the management between the heads of departments and their subordinates is fatal to discipline and to effective effort, and, in addition, the department head has for excuse, if things go wrong, that orders were given by others than himself. Excuses from a department head should not be entertained. Give him what he asks for, if it be reasonable, and then require results. If he cannot

get results, discharge him and get a better man who can.

The main requisite in regard to repairs is that they shall be made promptly and thoroughly. Nowhere is the old adage, " a stitch in time saves nine," more true than in the running of a power plant. At the slightest indication of something wrong in any part of the machinery, the defect should be immediately ferreted out and remedied.

Experience has shown that certain parts of the machinery are peculiarly liable to failure at short notice or without warning. In order to avoid costly stoppages it is imperative that such parts be kept in stock, ready to immediately replace the damaged ones. In fact, so great is the loss from stoppages that in most plants an extra power unit is warranted, to take the place, at a moment's notice, of one that is injured. When the plant runs fully loaded for only a few hours out of the twenty-four and one or more units are idle for a large part of the time, duplicates of those parts which are most liable to breakdown will usually be sufficient.

As to supplies, their cost is but a small part of the total operating expense, and the only requisite is that they shall be the best of their kind for the purpose.

One of the most important divisions of operating expenses and one which is most frequently slighted, or even altogether overlooked, is depreciation. The depreciation charge has been a source of much controversy both as to what it shall include and what the amount should be. It is a fund set aside each year from the income to provide for replacing any part of the plant that may become worn out or out-of-date, or that has to be replaced for any other reason. As already mentioned, it may also be drawn upon for any additions or improvements that may be required in order to meet competition or some other change in the conditions, where such extra expense does not result in increased net profit. The amount that it will be wise to lay aside for this purpose will depend much on the conditions of each case, and will vary widely for different plants and different localities.

Under administration charges may be included the purely financial and commercial features, such as accounting, canvassing, collecting, etc., features on which no good business man should need advice from an engineer.

INCOME

Show the average man a stream sliding down a steep declivity with its evidence of power, and he will wonder why some one has not utilised all this energy instead of allowing it to run to waste. If it be some lonely mountain stream, he will return to civilisation with glowing accounts of a magnificent water-power he has discovered, whose location most be kept secret for fear some other enterprising business man may step in and reap the rewards of his perspicacity.

In time he learns that the utilisation of this water-power means the spending of money, possibly of a very large amount of it; if he be wise, he will consult some engineering friend with experience in such things.

" What market is there for the power in the immediate vicinity ? " Market, forsooth! Will not manufacturers, users of power, jump at the chance of moving their factories to a place where power, that prime requisite of all modern production, can be had at a merely nominal cost ? Alas! they will not, unless there be also other attractions,—abundant raw material near at hand, cheap and efficient labour, and low transportation rates,—a combination rare indeed.

Even when all these favouring factors are present, hard and persistent work will have to be done before a market for the full capacity of the plant can be created. Manufacturers who are making money in one location will generally prefer to let well enough alone, and those who are losing money find it difficult to raise the money needed for transplanting their factories.

In most business enterprises the business man first sees the demand, then tries to meet it. In the matter of utilising water-power the process is often re-

versed; he sees the supply and then tries to find or create the demand. The method is faulty. Even if the power were offered to a manufacturer entirely free of cost, the cases are rare where he would be justified in moving for this reason alone. The ratio that the cost of power bears to the other factors in the cost of a finished product is usually very small, the cost of either raw material, labour, or transportation being in general of far greater importance. Unless, then, cheap and abundant raw material, a good labour market, and reasonable transportation rates can be also assured, no water-power, however inexpensive its development may be, can be considered a good investment unless a demand already exists for all the power it can furnish. It is clearly, then, of prime importance that either a demand for the power already exists or that the conditions are such that it can or will be created.

Now comes the most difficult and uncertain part of the problem. What is the highest price that can reasonably be asked per horse-power per year? At first sight the answer to this seems simple. Learn the price of coal and labour in the region where the power is to be sold; calculate, by methods well known to engineers, the probable cost of steam power, and then offer your power at a figure enough below this to make it attractive to the consumer. This seems very reasonable; but, unfortunately, difficulties arise in applying this method in practice. It may be safely said that not one steam-power user in a hundred knows what his power really costs. Most of them will estimate it from one-half to two thirds of its real cost, and cannot be persuaded that their estimate of its cost is too low.

Again, the power user in adopting the new power must either sell his steam-power plant for very much less than it cost him or must keep it, with the investment it represents, lying idle, and he must, in addition, invest in electric motors, since the power company generally delivers the power only in the form of an electric current at its premises, leaving him to install the necessary apparatus with which to utilise it. The quality of inertia inherent in human nature, causing opposition to innovation, must also be reckoned with. In view of these things, the safest course is to carefully canvass the region through which the power is to be sold and learn beforehand how much power can be sold and at what prices.

In this connection it must be understood that the sum of the capacities of the consuming motors may, under ordinary conditions, be much greater than the rated capacity of the power plant, for the reason that all the motors will never be consuming power at their rated capacity at any one time. Moreover, a water-power plant always has a certain capacity for overloads for short periods of time that will furnish the excess power required when an unusual number of motors happen to demand a heavy current at one time. Thus it is possible to contract to furnish power for an aggregate capacity in motors much in excess of the maximum capacity of the power plant.

Where current is furnished for both light and power, the heaviest load will usually come on at dusk in winter when a lighting load is added to the day motor load. This condition, however, lasts for only a short period, as the motors are soon shut down, leaving simply the lights to be supplied. The variation of the load is different for every plant, and the conditions have to be carefully studied in order to determine just how much excess motor capacity is allowable.

In general, the larger the number of customers supplied and the smaller the average capacity of the motors, the greater may be the excess capacity of motors contracted for. Incidentally, since the cost of power per horse-power is much greater in small steam plants than in large, a much higher charge can be made for power supplied in small units. Further, the larger the number of customers, the less is the variation in income by the loss of one or more customers. In short, it is desirable, from almost every point of view, to supply as many customers in as small units as may

be practicable. The supplying of lights in addition to power is also a great help, since the necessary extra expense is slight, compared with the extra income secured.

The distance to which power can be transmitted at a profit depends upon the price that can be obtained and the cost of transmission. This cost of transmission increases very rapidly as the distance increases, and the limit is soon reached when the interest on the cost of the transmission line will raise the cost of the power supplied nearly to an equality with the price that can be obtained for it. In some localities, where coal is poor and costly and steam power consequently expensive, it has been found feasible to transmit power at a profit over comparatively very long distances,—in one case 225 miles. Where good coal is cheap and abundant, 25 miles are about the limit to which power can usually be profitably transmitted.

Current Topics

THE overheating of dwellings, hotels, and public buildings generally is, in the minds of most people outside of America, a specific American characteristic. Certainly it is a feature of American life unpleasantly evident to the foreigner, and it is all the more noteworthy because American heating and ventilating engineers are inclined to flatter themselves that, so far as their specialty is concerned, they know a bit more than most engineers of other nationalities. Dr. Henry Mitchell Smith, however, in a paper read a short time ago before the Brooklyn Medical Society, makes the general statement that the principle upon which modern heating systems are based is all wrong. It is the sensible temperature upon which bodily comfort depends and not the temperature indicated by the ordinary thermometer, and the sensible temperature is something which is largely influenced by the degree of humidity of the atmosphere. To humidity, however, the modern heating engineer has given very little attention, and the result is that we frequently find indoor winter temperatures of a dried-out atmosphere at anything between 70 and 76 degrees with far less comfort than would be experienced at 65 or 68 degrees in a suitably moistened atmosphere. As to this, Professor Warren S. Johnston is quoted by Dr. Smith as having said,—" It is a curious fact that it is only through the moisture in the

air that it retains heat. Heat naturally radiates from all bodies that are warmer than their surroundings; if the air has little or no moisture in it the radiated heat goes right through it without warming it, but if it is moist it stops the radiated heat, and heat warms it. If it were not for the moisture in the air it would be too cold to live in. Humidity in the air is nature's great bed blanket for her children, without which they would all perish; so, likewise, moisture in the living room acts as clothing and helps to keep us warm."

COMMENTING upon the above, Dr. Smith remarks:—"A moment's consideration shows that the prevailing practice of depending upon the thermometer as the sole guide in the heating of buildings is not only inadequate and unscientific, but it is often misleading. It is not sufficient to know only the temperature if we desire either comfort or health, for the same temperature produces varying sensations of warmth or cold, depending upon the relative humidity at the time existing. It is unscientific and arbitrary to lay down a fixed temperature as a standard for living or sleeping rooms unless the relative humidity is indicated as well. The same air temperature is not the same in its effects at different times, because the relative humidity varies, and unless more moisture is supplied to the air which we obtain from outside by various methods of ventilation, the relative humidity indoors becomes unusually low in cold weather, because of the great difference between the indoor and outdoor temperatures. Even though the relative humidity may be fairly high out of doors, the absolute humidity will be low, on account of the low temperature of the air. At New York and along the Atlantic coast the prevailing winds during cold periods are usually from the north or northwest, having passed over a dry, frozen area which has presented little opportunity for the air to take up moisture. At such times the temperature of the air indoors is allowed to become as high as 76 to 78 in order to feel comfortably warm. Records from steam-heated apartments show that the relative humidity was sometimes as low as 25 per cent., with a temperature of 78, during a period of very cool weather in January, 1902. The high temperature is necessitated by the chilling of the body by the increased evaporation, evaporation being essentially a cooling process. It is needless to say how unhygienic as well as uncomfortable is such a distortion of the proper relationship between temperature and relative humidity. By regulating the indoor relative humidity we could keep the room temperature much more nearly stationary, irrespective of the temperature outside. But no improvement in indoor atmospheric conditions can be expected until heating engineers and the people whom they serve realise that with the ever-varying absolute humidity out of doors no system of heating can be made satisfactory if the indoor relative humidity is disregarded. Even thermostatic temperature control will not fill the requirement, for a constant temperature is constant in its effects only if accompanied by a constant relative humidity."

HEATING systems with air moistening accessories of approved kind are common enough in some manufacturing plants,—cotton mills, for example,—in which carefully controlled moisture percentages in the atmosphere are vital factors in the successful operation of the plant. Curiously, however, these do not seem to have suggested the propriety of similar installations for the benefit of human beings. In the conventional type of American hot-air furnace for dwelling-house heating, we have the water-pan method of moistening the air; but in many households its purpose is but vaguely understood, and the attention which is given to it by servants is scant. At its best, moreover, it is an inefficient contrivance. Where steam or hot water heating is used in a dwelling house, no pretense whatever is made at air moistening.

Dr. Smith's paper, therefore, ought to prove interesting and profitable reading to everyone. Properly appreciated by the heating engineer, it ought to stimulate action towards much-needed rational reform in heating practice. The way in which unduly dry hot air, of the kind ordinarily found indoors during the winter season, helps to swell the ills of mankind, is thus outlined by Dr. Smith:—The skin and the mucous membranes of the respiratory passages are the principal sufferers, since these tissues are always kept moist with their own secretions, and from them water is freely abstracted to satisfy the large saturation deficit in the air breathed, such air, passing with every inspiration over the moistening surfaces nature has provided in the mucous membranes, calling for an enormous output of the fluid elements of these tissues. This leads to glandular over-activity and its consequent evils, catarrhal inflammation and others.

WHILE the steam engine indicator cannot help to give us a steam turbine diagram that would mean anything, the statement, often made, that the steam turbine cannot be "indicated" is not altogether true. Writing in *The Electrical Review*, of London, Mr. William H. Booth says that the pressure in the turbine can be gotten at any part of its length, and from this something can be learned of the behaviour of the steam within, and particularly of the effects of superheated steam. Where saturated steam is employed in the turbine, its temperature at any point can be ascertained by means of a mercury pocket of thin brass let into the body of the outer casing. A series of these pockets, placed along the length of the turbine, and fitted with thermometers, will give a series of temperature readings at such points which can be plotted as a curve of pressures by the aid of a steam table, or the thermometers may be graduated in pounds to avoid translation. A series of pressure gauges may also be used, and will correspond with the thermometer readings at the same section. The rate of expansion can be found in this manner as an aid in fixing upon the dimensions and proportions of the several parts. Where superheated steam is employed, the difference of the readings of the pressure gauges and of the thermometers will show the extent to which the superheat is retained as the steam travels through the turbine. The constancy of the conditions in a turbine on a steady load renders such methods of investigation easy and reliable. In this respect the turbine differs from the reciprocating engine, the results from which, by any similar method, would be speculative only.

THE extent to which oil is used as a locomotive fuel in America is well illustrated by the Southern Pacific Railroad Company, on whose system, at the present time, 780 out of 1350 locomotives owned by the company are burning oil. The engines at present continuing the use of coal are on divisions of the line where coal can be obtained at a lower price than its equivalent in oil. The change from coal to oil is comparatively simple, and should the oil supply run short, or increase in price to a point which would make a return of solid fuel profitable, the burning of coal could be resumed in a short time. Oil also has been substituted for coal fuel in the company's shops at Sacramento. In connection with these particulars, taken from *The Engineering and Mining Journal*, that publication tells a story which proves that managers of a great railroad company are not always prophets. The Southern Pacific had a large land grant from the government in the San Joaquin valley in California. Much of this land was considered worthless on account of its aridity, and was graded at very low prices. A few years ago the company sold a tract in the valley for $1600. Some time later, when oil was discovered in Kern county, it was found that this tract was the centre of the great Kern river oil-field. The company tried to buy it back, but the price asked was $4,000,000, and no bargain was made. A contract was made,

THE NEW WHITE STAR LINE STEAMSHIP "BALTIC," THE LARGEST SHIP EVER BUILT. LENGTH, 724 FEET; BEAM, 75 FEET; CARGO CAPACITY, 28,000 TONS

however, with the owners to furnish oil to the railroad, and the company is now paying about $1500 per day for oil from the very tract sold originally for $1600. It seems somewhat strange that the sale should have been made, since oil had already been found in the valley at the time; but apparently the railroad company's land department had not much geological talent at its command.

By far the largest ship ever built, not excepting even the famous *Great Eastern*, is the new twin-screw White Star Line steamship *Baltic*, which left Liverpool for New York on her maiden voyage early in July. She is 726 feet long, 75 feet wide, and at load draught displaces 40,000 tons, her capacity for cargo being about 28,000 tons. Her engines are of 14,000 indicated horsepower, and 250 tons of coal per day are burned in her boilers. The vessel in its entirety, with the exception of a few auxiliaries, was built at the yards of Messrs. Harland & Wolff, at Belfast, Ireland. There are two sets of four-cylinder quadruple-expansion engines. The high-pressure cylinders are 33 inches in diameter; the first medium cylinders, 47½ inches; the second medium cylinders, 68½ inches; and the low-pressure cylinders, 98 inches in diameter. The stroke is 63 inches. Steam is furnished from eight Scotch boilers, each 15½ feet in diameter and 19½ feet long. The *Baltic's* speed is only about 17 knots, the ship having been intended to meet the want of an increasing number of travellers whose first desire is not great speed, but the largest modicum of comfort coupled with moderate speed. Experience having shown that this desideratum is fulfilled in the *Cedric* and *Celtic*, it merely remained for the White Star Line to introduce a vessel of the same type, but still further improved by the addition of such minor embellishments as only a careful and far-seeing management could anticipate. The *Baltic* can carry 3000 passengers, besides a crew of about 350. One of the novel features of the *Baltic's* equipment is her electric heating and cooking appliances. These comprise electric plate warmers, griddles, and egg boilers, water heaters and dough mixers. Electric motors, too, are used for driving roasting spits, the whole outfit exemplifying in a very interesting manner how far-reaching the ship-board conveniences of electric transmission may be made.

Carrying a 50,000-volt current a distance of 85 miles and delivering in the neighbourhood of 10,000 horsepower, as is done in the case of the Shawinigan Falls electric plant in Canada, is an engineering achievement of the first magnitude and importance in even these days of remarkable electrical undertakings. The Shawinigan plant, in fact, demonstrates perhaps a bit more strikingly than most others of allied character, what remarkable results in the development of a certain locality may be reached by a judicious exploitation of its power riches, for Shawinigan to-day, a city of rapidly widening limits and growing manufacturing interests, was practically non-existent four years ago, when, as Mr. Wallace C. Johnson told in one of the articles in the recently issued "Electric Power Number" of this magazine, the canoe was the only means of access to the place. The electrical part of the enterprise was carried out by Mr. Ralph D. Mershon, as consulting and supervising engineer, and represents the fulfilled promise of excellent work to be done which was given by his earlier attainments in high-tension transmission engineering. The installation, as it stands to-day, is one of the best existing examples of what may be hoped for from hydraulic and electrical engineering skill combined in the face of great difficulties to be overcome.

So far as any real advance in blast furnace practice during the past decade is concerned, either in recovering flue dust or in washing the gases, there is not much to be said. According to Mr.

E. A. Uehling, in a discussion of the subject at a recent meeting of the American Institute of Mining Engineers, briquetting the flue-dust has not proved commercially successful. Filling it back into the furnace, as fast as produced, is largely practiced with varying and, on the whole, indifferent success. The difficulties arising from the use of the large percentage of fine ores in the mixture are very materially aggravated by filling back the flue-dust. Hence the problem of treating the latter so that it can be utilised without serious difficulty still remains unsolved. Since in American practice from 2 to 5 per cent. of the burden, depending on the percentage of Mesabi and other fine ores in the mixtures and also on the size and condition of the furnace, is blown over, the solution of this question is of vast importance. It has been proposed to mix the dust with a sufficient proportion of pulverised slag, and expose the mixture to a temperature high enough to melt the latter, thus agglutinising the mixture. Mr. Uehling believes that with the proper means the dust can be agglutinised by hot molten slag direct without the aid of external heat, with greater probability of commercial success. Far more important, however, than the preparation of the flue-dust is the proper purification of the gas. In the United States nothing of significance has been done in that direction.

EDWIN WILBUR RICE, JR.

Technical Director of the General Electric Company

A BIOGRAPHICAL SKETCH

IN the building up of every great manufacturing organisation there has to be some one man who is primarily the engineer. Such a man has pivotal individuality, expressed in the conception of ideas and in the overcoming of difficulties that arise in the reduction of ideas to practice. Among the strong personalities that have built up the organisation of the General Electric Company, that of Edwin Wilbur Rice, Jr., is one that fulfills, in a singularly complete degree, the ideal of the modern engineer.

At eighteen, Rice graduated from the Philadelphia Central High School. During his last two years of school work he assisted his teacher, Professor Elihu Thomson, and showed an exceptional aptitude in making special apparatus. The fact that he graduated high in his class made the step he took in beginning his practical career a decision requiring a deal of resolution and knowledge of his own mind. This step involved the giving up of a college course, and, instead, the deliberate choice of electrical work with his old teacher, first at the little shop in Philadelphia where the early arc light dynamos were built, and later at the works established by the newly formed American Electric Company at New Britain, Conn.

The two years that ensued developed the faculties of young Rice in a hard school of deferred business hopes, for "results" did not seem to come, in spite of persistent industry. Then came the memorable business visit of Messrs. H. A. Pevear and Silas A. Barton to the struggling New Britain works. Coming from Lynn to buy an electric light plant, their trip resulted in the acquisition of the business itself and its transfer to Lynn under the name of the Thomson-Houston Electric Company. Mr. C. A. Coffin's ability also became associated with the enterprise, and Rice had time to work at that which was nearest his heart,—the invention, often

in conjunction with Prof. Thomson, of essential adjuncts of the "Thomson-Houston arc light system."

Many a bright young fellow, in his situation at this period, would have been stalled in a hopeless rut of mere experimenting. Rice was exceptional, with a progressive mind able to hold every gain in his work and to turn setbacks into useful schooling with its full fruition of experience and character. He lived with the business, becoming a factor, a human pledge of its ultimate success. And success meant that there was no room or time for anything but the most practical work. Dynamos and lamps had to be made quickly, had to find a market, and stay sold,—stern business conditions that kept young Rice's alert intellect well away from the narrow and impracticable, and sharpened his perceptions, by the same high destiny that ruled out the inoperative or uncommercial in the material product of the works. The backward glance upon his personality at this period shows how definite was his trend toward the constructive, how sure his grasp on essentials.

The hard-headed business men who had carried the new enterprise through to the beginning of its larger life had had their eyes upon Rice. They offered him the superintendency of the works, although he was still well under thirty years of age. His training had led up to just the very adequateness that his new work required. From the early days the overcoming of detail difficulties had formed in him the habit of meeting things squarely and giving a good account of them. To the old inventive faculty and resourcefulness he now had to add variants of these qualities,—grasp of the principles of shop system, ability to get work out of men, quick choice of the right course in the face of difficulties. The result is well expressed by his old master and colleague, writing appreciatively of him as he was at this period:—

"Under his able and tactful management work was systematised, production hastened, and cost cut down."

Rice had arrived at his calling, and it was that of an engineer. When the consolidation with the Edison General Electric Company came in 1892, bringing with it the comparatively great increase of plant to be handled, it was but a more extended field for the exercise of these qualities; the rate of growth of the man fairly matched the larger issues. Expressed in externals, the Lynn methods of organisation and factory management developed in scope, without change in principle, at Schenectady. The personal history of the man became the history of the General Electric Company's development of the electrical arts. In 1893 he became chief engineer, adding the duties of this position to his work as technical director, and in 1896 was made third vice-president of the company and placed in responsible charge of its technical and manufacturing departments. During that time,—or the last nineteen years,—he has been the man *par excellence* responsible for the harmonisation of the technical with the commercial development of this corporation.

It is quite possible to trace the success of the man to its source. The channels of work through which Mr. Rice advanced required from the first that he be a discoverer of men and a judge of inventions. His resourcefulness, business ability and training made him eminently competent to handle a busy manufacturing plant; but it is his singular insight that enables him not only to see to the very bottom of the numberless new inventions to which his attention is directed, but to find also the special talents that may be latent in men. This faculty multiplies his personal efficiency enormously beyond that of the mere inventor, however prolific of ideas the latter may be.

The career of Dr. Charles P. Steinmetz, whom Mr. Rice may justly be said to have "discovered," furnishes a striking instance of his knowledge of men on his part. His selective faculty applied to inventions is equally keen. He recognised the essential value of the rotary converter, and led his forces to the successful attack of some knotty problems of its development, the timely solution of which gave his company a commanding position in opening up this

field. The development of the modern revolving field generator was a kindred achievement. Although it was almost unknown in this country, he selected it in preference to the "inductor armature," using no moving conductors, which, he intuitively realised, was an extreme construction with inherent shortcomings. At a critical period in the history of the electric railway he favoured the radical departure of taking the motor off the car platforms and flexibly suspending it from the truck. This step flatly opposed engineering precedent, but proved to be a long stride in the perfecting of electric traction. His immediate realisation of the value of the carbon brush for commutation was a related instance, in which his remarkable ability to see the whole value underlying an invention helped notably to establish electricity in a new field of usefulness. Here was the work of an engineer,—the grasping of vitally important inventions and their use in a masterly, co-ordinated improvement of a whole art.

In the field of actual invention Mr. Rice has also shown much originality, and more than a hundred patents have been granted to him in this country. His work in connection with the Thomson-Houston arc light system has already been mentioned. The supremacy of his company in the equipment of high-voltage stations and transmission is largely due to his talent and energy in developing devices and methods for handling and controlling high-pressure currents.

Drawn into the commercial execution of his ideas, he proved that he could not only invent and simplify, but could adapt his inventions and improvements to their manufacture, remaining always keenly alive to the commercial requirements of the present and future. From a factory of a few hundred men employed at Lynn when Rice took charge in 1885, grafted seven years later in the Edison Works, there has developed the present General Electric Company,—an organisation employing a normal aggregate of over 20,000 men and utilising 4,000,000 square feet of floor space at its three great plants. Under his hands a small plant for the tentative manufacture of arc lamps and dynamos has become the world's greatest works for the production of all the appliances of modern electrical engineering.

With such a task as his a man must be a general, realising his responsibility as the head of an army of material and financial forces, but undismayed by such responsibility and clear-headed at all times in executing a steady forward movement amid conditions constantly changing. If disappointments occur whereby the most carefully laid plans are threatened by the failure of others to fulfill their contracts, he must have alternative plans, or must be able to evolve them, whereby the labour and money and material at his command shall suffer no interruption to its continuous employment. The enormous modern growth of electrical applications has intensified the value of this faculty to the electrical engineer, as compared with the builder of bridges or railroads. Indeed, the personal success which Mr. Rice has attained goes far to explain the prominence of electrical engineering among the older branches of the profession.

Mr. Rice is a member of the American Institute of Electrical Engineers and of the American Association for the Advancement of Science in this country, and a member of the Institution of Civil Engineers and of the Institution of Electrical Engineers in Great Britain. After the Paris Exposition of 1900 he was created a Chevalier of the Legion of Honour, and Harvard University last year conferred on him the degree of Master of Arts. Quite recently he was made a director of the General Electric Company.

D. McFARLAN MOORE

THE PHOTOGRAPH FROM WHICH THIS PLATE WAS MADE WAS TAKEN BY MARCEAU, OF NEW YORK, BY THE LIGHT OF A SET OF MOORE VACUUM TUBES

SEE PAGE 445

CASSIER'S MAGAZINE

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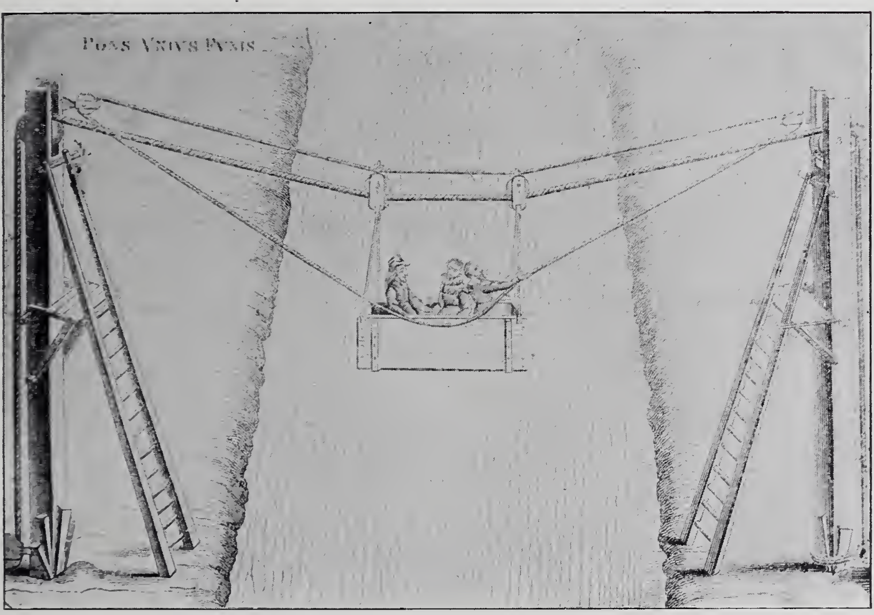
TRANSPORTER BRIDGES

AT NANTES, BIZERTE AND ROUEN



A TRANSPORTER BRIDGE OF THE SEVENTEENTH CENTURY

FROM AN OLD PRINT

CROSSING rivers by means of a movable platform suspended by cables from a truck travelling on an elevated runway has been done on the European continent for several years past and has proven a successful substitute for the ordinary bridge or ferryboat. The cost of the tranporter bridges which serve this purpose is materially less than that of suspension bridges, and their advantage over ferryboats further consists in the absence of tide effect and in quickness of transportation.

The latest addition to this type of

THE BRIDGE FERRY AT BILBAO, SPAIN

THE TRANSPORTER BRIDGE ACROSS THE LOIRE AT NANTES, FRANCE

bridge is that recently completed at Nantes, France, and another is now in course of erection at Duluth, Minn. This will be the first of its kind in America. Other transporter bridges are in use at Bilbao, Spain, at Martrou and at Rouen, in France, and at Bizerte, in Tunis.

THE SUSPENDED FERRY AT NANTES, FRANCE

By Benjamin H. Ridgely

The practical advantages of the "pont à transbordeur" as it is called in France, for crossing swift, narrow streams and deep cuts or channels are so many and so apparent that it seems surprising that this class of bridge or ferry has not been generally adopted all over the world, and particularly for traversing narrow streams, cuts or gorges. It seems particularly suited for fast traffic in cities where canals and other narrow streams, crowded with shipping, are to be traversed. The "pont à transbordeur" is a patented invention of several French engineers, of whom the best known is Monsieur Arnodin, of Chateauneuf-sur-Loire, Loiret. In an interesting pamphlet the inventors call attention to the fact that the crossing of channels has always been a matter of difficulty to engineers, particularly when the channels are in the vicinity of tidewater and consequently exposed to tidal waves and currents. The greatest obstacle springs from the fact that channels must be kept clear in all sorts of weather, with a free passage for the highest masts of vessels in order that navigation may not be interfered with.

Until the "pont à transbordeur" was invented, the engineer had at his disposal for solving the problem draw, swing, and bascule bridges and ordinary ferryboats. The last, whatever their motive power, are always more or less uncertain in swift channels, particularly in tidewater, since their landing places must be regulated by the tide level, thus often making it necessary to use steep and dangerous approaches at low water.

Then there are storms and fogs to be contended with, to say nothing of ice, any of which may seriously interrupt ferryboat service.

On the Clyde in Scotland, ferryboats are used with movable platforms which may be raised or lowered to suit the tidal level; but these are comparatively heavy, clumsy affairs, requiring much power and attendance.

Draw, swing and bascule bridges are always clumsy and are available only for channels whose water-traffic may be suspended at will and whose shipping is at approaches must generally be built for all stationary bridges.

It is, therefore, not remarkable that ordinary bridges over navigable channels are relatively few in number. Tunnels may often be resorted to, but the fact remains that this is seldom done when a bridge or ferry may serve the same purpose.

It is claimed for the "Pont à transbordeur" that it easily disposes of all the difficulties here cited. In the first place it is built high up over the channel and leaves the water-way free at all

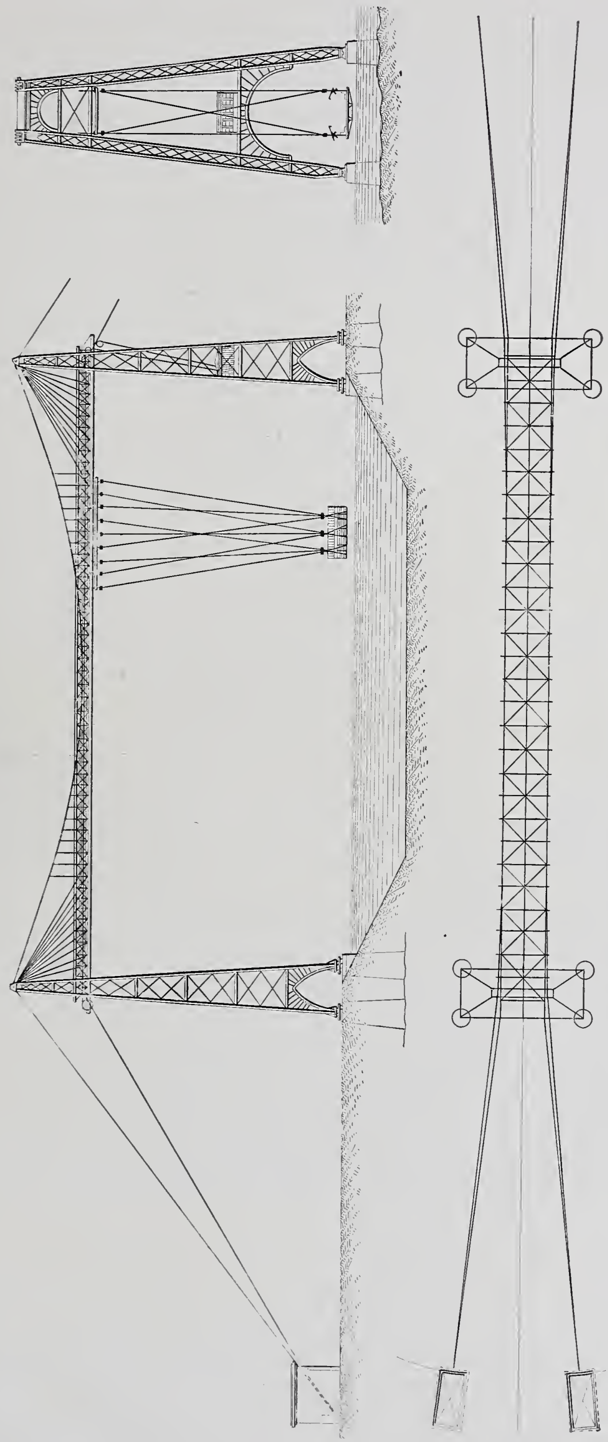
THE SWINGING FERRY CAR AT NANTES MAKING A LANDING

all times under perfect control. They can be used practically only over inland rivers and docks or interior canals. Near the sea they are not practical for the reason that ships seeking refuge from bad weather, and not knowing the signals or not always under perfect control may find them to be dangerous obstructions.

Of course, suspension bridges or other ordinary bridges may nearly always be employed; but if they are to be used over rivers leading to or forming any part of a busy harbour, they must be built high enough to permit all ships to pass under them, and this would mean a height of about 200 feet above the water line. Besides, very expensive hours. Secondly, there are no tortuous ascents or descents or difficult approaches. The swinging ferry rolls smoothly up to the bank, street or quay, and permits the traffic to come aboard, as if continuing its level passage along the street or road.

In the third place, it is faster than an ordinary ferryboat, and can be operated with much more regularity. Being built on an air line, it uses the shortest possible distance for the crossing; the motive power for operating is comparatively small, and can be developed by any kind of motor; and the cost of construction is relatively small.

The transporter bridge at Nantes is a graceful structure, consisting of two tall



PLAN AND ELEVATION OF THE BRIDGE FERRY AT BIZERTE, TUNIS

AN END VIEW OF THE BIZERTE BRIDGE FERRY DURING CONSTRUCTION

steel towers, one on each bank of the river, and joined together by a horizontal bridge or railway track 490 feet long and 165 feet above the surface of the water. An inverted steel carriage or car travels along the rails, and suspended from this by steel cables is the platform or "ferry," which has two divisions, one for horses, vehicles and railway cars, and the other for foot-passengers. Electric power operates the car from which the ferry is suspended, and the crossing is thus quickly and easily effected. The cost of the

structure fully equipped was about 800,-000 francs.

It was begun in September, 1902, and was operated the first time on October 22, 1903. Each of the four feet of each column rests upon a separate base built of masonry. The height of each column above the water is 250 feet, and each column has seven landings. The topmost landing is used for an observatory, and visitors may have a fine view of the city by climbing up to it. Each of the columns is capped by a steel plate or roof, weighing 8800 lbs. upon which the steel cables supporting the structure are strung.

The Nantes transporter differs from all other similar structures in construction. All other transporters are built upon the model of ordinary suspension bridges; that is to say, the ordinary structure is sustained by cables strung from column to column. The Nantes structure, on the other hand, is built on the cantilever principle, as will be noted, from the illustration on page 437.

The motive power is electricity. Two stationary motors, each one working in turn, rest upon the rear extension of the runway, on a level with the rolling trucks from which the ferry is suspended. These motors operate a cable, to which the trucks are attached. The cable, winding upon a windlass, passes under the bridge in one direction and comes back above it in the other direction. The movement of the windlass is reversible.

The engineer who directs the movement of the ferry-car occupies a place in a little observatory tower on top of the car. He can stop the car and can go forward or backward at will.

The transporter truck is designed to carry a dead weight of 30 tons, and the crossing is made in exactly one minute. The average power necessary for operating the transporter is 10 horse-power; this may be reduced to 5 or 6 horse-power when there is no wind.

The Nantes bridge was built at the works of Monsieur Arnodin at Chateauneuf-sur-Loire, Loiret, France. In its construction, M. Arnodin found it necessary to use many tools which he invented and made especially for this work.

THE BRIDGE AT BIZERTE, TUNIS

By M. T. Hugues

The transporter bridge at Bizerte, Tunis, connects the cities of Tunis and Bizerte. It is located at the head of two large intercommunicating lakes, running inland from the shore of the Mediterranean.

The first and most extensive of these lakes has a depth ranging from forty to fifty feet, and affords spacious and safe anchorage to shipping of the heaviest tonnage. A short natural channel, formerly about five feet deep, connects this lake with the outside sea; but the French Protectorate, with a view to creating a harbour for ships of war, excavated this channel to a width of three hundred feet, and a uniform depth of thirty feet, thus facilitating access to the lake anchorage.

The opening of this channel cut the communication of the route between the cities of Tunis and Bizerte, and as the traffic was considerable, a steam ferry was installed in 1892. It soon became apparent, however, that with the increase of traffic, this ferry was utterly insufficient. The Board of Public Works of the Regency found it imperative to provide a means of facilitating communication, and, after considerable study of various projects, finally decided to adopt the plans of Messrs. de Palacio and Arnodin for a bridge-ferry.

The contract for its construction was awarded under the following imperative conditions:—

First, there should be no obstacle to the free passage of shipping at any hour, necessity of special signals or of slowing up; second, it must be possible to carry on land-traffic from one side or the other of the channel without ascen-

THE BRIDGE FERRY AT ROUEN

A NEAR VIEW OF THE SUSPENDED CAR

sion over any elevation, and there should be no increase of distance for travel.

These conditions were accepted and the ferry was built. It crosses the channel at a sufficient elevation to allow room for the tallest masts of vessels frequenting the port. A truck operated by cables worked by a stationary steam-engine runs along the bridge, and suspended from it in the usual way, is the passenger platform reaching the level of the quays, and affording communication to, and from, either side. The runway is 143 feet above the quays and 152 feet above sea level.

The towers are 355 feet apart and rest on masonry foundations. The traveling platform of the bridge is thirty feet long by twenty-three feet wide. The middle portion, fifteen feet wide, is for vehicles and cattle, whilst on either side a pathway, four feet wide, is left for standing passengers. The entire superficial area amounts to 690 square feet, and, excluding vehicles and cattle, would afford accommodation for 270 foot-passengers.

The space reserved for carts would enable two heavy waggons or four light carriages to stand abreast. In case this space should be entirely occupied with vehicles, there would still remain on the side-paths accommodation for ninety foot-passengers.

The engine working the platform is installed in one of the towers, giving the operator a good position for observing the channel. The motor itself is a stationary steam-engine of about fifteen horse-power. There are two boilers, one of them being always held in reserve in case of emergency.

The contract for the building of the bridge was made in 1896, and the cost of the finished structure was $107,000 (£21,400). Two years were occupied in the work, the bridge being finished in the early summer of 1898, since which time it has been in satisfactory service. Shortly after its completion, its stability was strikingly demonstrated. The region of Bizerte was visited in November, 1898, by a cyclone.

The engineering works of the jetties were seriously damaged by the storm, but the bridge structure showed no signs of the slighest injury.

In concluding this sketch it is interesting to note that the Protectorate Government is now seriously contemplating the advisability of demolishing and removing the Bizerte bridge-ferry. It is proposed to increase the width of the channel, which at present has been proved to be inconviently narrow; but the principal reason for removing the bridge is that, on account of its height, it would present a good target for gun fire from a hostile fleet.

It has been proposed to transport the structure bodily either to Bordeaux or Brest, and to change the motive power from steam to electricity. As to this, however, nothing definite has yet been decided.

THE ROUEN BRIDGE

By Thornwell Haynes

The bridge at Rouen, across the Seine, is not unlike the one at Bizerte. The "transbordeur" is driven electrically, current being taken from the electric railway system of the town.

The towers on each side of the river are 221 feet in height, the distance from the overhead girder to the water-level being 164 feet. The carriage, or suspended car, is 42 feet long and 36 feet wide, and is carried on 30 cables of 140 feet length. It weighs 45 tons, and though the average load it carries amounts to about 15 tons, it has been proved by experiment that a cargo of 100 tons is by no means straining its capacity dangerously. The journey from quay to quay is made in 55 seconds. The carriage conveys passengers, waggons, and street cars.

VACUUM-TUBE LIGHTING

By D. McFarlan Moore

A PHOTOGRAPHIC STUDIO ENTRANCE LIGHTED BY MOORE TUBES

THE first commercial installations of vacuum-tube lighting, which imitate daylight in colour and diffusion, are now accomplished facts, and vacuum-tube lighting is destined to occupy a position in applied science comparable to that now held by other great modern improvements. The principles upon which it is based were known for many decades before it came into practical use, just as the principles of all other great developments from the telephone to the incandescent light were known.

Many scientific papers have been written during the past twenty years about "the light of the future," but these commenced to be proven when, early this year, there appeared in the city of New York the first commercial installation of vacuum tube for the purpose of general illumination. A few months previous to this time vacuum-tubes had been applied to photographic purposes, but the above noted installation was the first instance where a bona fide vacuum-tube was used for commercial electric lighting, displacing arc and incandescent lamps.

The problem of developing a new form of illumination based upon the principle of using a gaseous electrical conductor as a light source has commanded the attention of the greatest of

A DRAWING ROOM WALL AND CEILING EFFECT OBTAINED WITH MOORE TUBES

scientists for many years, yet, until comparatively recently, the practical results have been extremely meagre.

Many experimenters have laboured with vacuum - tubes of innumerable forms. The term "vacuum-tube" is used, broadly, to describe simply an enclosure in which the pressure is less than that of the surrounding atmosphere, the continued gases or vapours being electrically agitated. However, the writer would here deal only with that class of vacuum-tubes in which the gaseous conductor is used as a source of light.

Probably the first vacuum-tubes of this character were the barometers of the monks of the Middle Ages While being carried through dark hallways a very faint glow was detected, due to the electricity caused by the friction of the mercury acting on small quantities of residual gases and mercury vapour. It thus appears that the first electric light was a vacuum-tube and a mercury tube at that. Many years later, about 1854, Geissler (a name that should never be forgotten) sealed a platinum wire into each end of a small glass tube, partially exhausted it and attached the wires to an induction coil—the result, on the passage of current, being a feeble light which has never ceased to excite interest even though it lasts for only a very short time.

The many difficulties in the way of making a commercial vacuum-tube lamp have been almost insurmountable, but if there was any difficulty more pronounced than the others it was to produce a light that would have a commercial life. Over six months, however, have now passed, and the already mentioned first practical installation has run continuously without any attention whatever, and is to day in exactly the same condition, as proven by accurate electrical and photometric measurements, in which it was on the day it was started. It is a 2-inch tube, 43 feet long, bent back and forth upon itself in a horizontal plane, forming an artificial skylight.

That the success of this first installation is a matter of great importance is appreciated by all who realise the enormous gulf existing between laboratory or electrical show demonstrations and thoroughly practical commercial lighting.

Some investigators gave much attention to the electrical conditions supposed to be necessary to successfully operate vacuum-tubes, such as resorting to currents of enormous potentials and frequency, obtained by using the troublesome disruptive-discharge spark-gap with interrupters, condensers, etc. With such currents, bulbs were generally used, thus retaining the unit or spot idea in lighting. The bulbs were constructed with but one electrode, terminating in a small ball at the center of the bulb—the idea being that the air molecules, due to the electrical agitation, would not only bombard the ball to incandescent but also form a photosphere of incandescent air molecules around it.

Simple closed glass tubes devoid of any electrodes whatever have been made to glow faintly when in an intense electrostatic field by induction, the energy passing from an electrode of the potential source through the intervening air, then through the tube, and again through the intervening air to the other potential electrode. One reason, of many, why these lamps were not successful was that air molecules were not at all suitable and a lamp could not be made to last more than a few minutes.

There are two general forms of electrodes that can be used in vacuum-tube lamps of this character, that is, internal electrodes and external electrodes. In the former the electricity passes directly over a metallic conductor through the glass and therefore comes in direct contact with the attenuated gaseous-conductor. In the latter form the electrical energy is applied to the exterior of the receptable only and its energy is transmitted to the attenuated gas entirely by electrostatic action. Combinations of these two general systems have also been tried

Many have endeavoured to solve this problem of the production of artificial daylight by varying the character of the material of the electrodes (internal espe-

cially) in the hope that a material could be obtained which would not only act as the electrode, but also furnish the gaseous conductor so that an efficient form of light would result. In this quest mercury has been attractive for many years, and recent investigators should be given much credit for further perfecting the methods of using it; but there is very little doubt that mercury will not figure in the final solution of the problem at all, because unfortunately its spectrum is entirely devoid of any red rays, and it can not therefore be considered in any way an imitation of daylight. Further than this, the ideal light must be one that will operate from alternating currents because the time is rapidly approaching when direct current will be entirely supplanted by alternating current. Mercury thus far has not shown itself applicable for use with alternating currents, and when used with direct currents the character of its electrical action is entirely different from that of an alternating current vacuum-tube, in that, in an alternating current vacuum-tube there is a complete and distinct flash of light from one end of the tube to the other for each alternation of the electric current. But with the mercury tube on direct currents the electricity flows through the tube in identically the same manner as the electricity flows between the two carbons of an arc lamp. In fact, the mercury tube is simply an enclosed arc lamp using mercury vapour to greatly increase the length of the arc.

The most striking practical difference between a tube " burning mercury electrically " and a genuine vacuum-tube is not in their colours—because they both look white—but in the colours which they respectively give surrounding objects. The entire absence of red in the spectrum of mercury makes almost everything appear so extremely objectionable that for illumination purposes the mercury light is impracticable.

However, the time is not far distant when direct current, arcing, vacuum-tubes will be made commercial, especially in short lengths, without the use of mercury but with a daylight spectrum. Owing to the large number of direct-current circuits now in use, the immediate value of this branch of this system of vacuum-tube lighting is enormous.

A fact that has been singularly overlooked in the past is that the most important factor in any vacuum-tube lighting system is the gaseous conductor. Heretofore but little definite work has been done on this particular phase of the problem. The light phenomena due to various degrees of vacuum have been carefully noted, but no serious attempt seems to have been made to find the proper chemicals from which to produce a gaseous conductor that would have correct colour values and be otherwise suitable to actually light, for example, both brightly and efficiently, and that would last. The goal seemed to be too far away to be reached. When finally found, the ideal gaseous conductor will not only have practically all of its luminous energy located in the visible spectrum, but also have the correct proportionate amount of each of the colours to give objects appearing under it their exact natural shades.

A quarter of a century ago the great problem in electrical illumination was to find out how to make a suitable filament for the incandescent lamp; to-day, it is to find the gaseous conductor for the vacuum-tube lamp. It is purely an electro-chemical problem—in many respects the most important of electro-chemical problems, and yet few professors definitely realise that there is such a problem, and no text-books even mention it. Since the tubes must be transparent, they will probably remain of glass, and it is fortunate that the problem is not complicated by the glass being acted upon by the gaseous conductor. Of the thousand and more gaseous conductors already tried, none of those which were at all hopeful had any effect on the glass. At best, the work in connection with simply trying large numbers of different gaseous conductors is great, but it is further very much augmented by the necessity of repeating tests with the same gases many times and under different conditions, in order to determine the critical pressure, or

A COUNTING ROOM LIGHTING EFFECT. THE MOORE TUBE HERE USED IS 154 FEET LONG AND 1¾ INCHES IN DIAMETER

degree of vacuum, at which each gaseous conductor operates best.

To be at all promising as a light producer, a gaseous conductor must fulfill at large number of exacting conditions, the most salient of which are, that it should be capable of giving a light of high intensity, of high efficiency, of long life, and of daylight colour values.

None of the ordinary gases found in nature, either singly or in combination, will even approximate to these specifications. The gaseous conductor that is now commercially fulfilling these conditions is manufactured under special conditions and is found to be equally applicable to tubes in which the ionisation is either permanent or intermittent. Outside of the utilisation of the discovery, vacuum-tubes giving a similar light have never been made to hold their watt and light measurements absolutely constant even for a few moments, and the fading away of their entire luminosity is a matter of only minutes. Therefore this new gaseous conductor represents an enormous advance over anything heretofore known for this purpose; nevertheless it falls far short of giving the extraordinary efficiency that theory shows to be possible.

There are many theoretical reasons for believing that by electrically agitating gases, vastly improved efficiencies can be obtained; but the principal one is that the proportion of the visible rad-

iations to the total radiations depends largely on the chemical constituency of the gaseous conductor and not, as with solids, like the incandescent lamp filament, on the temperature. The study that has been given to the gaseous en-

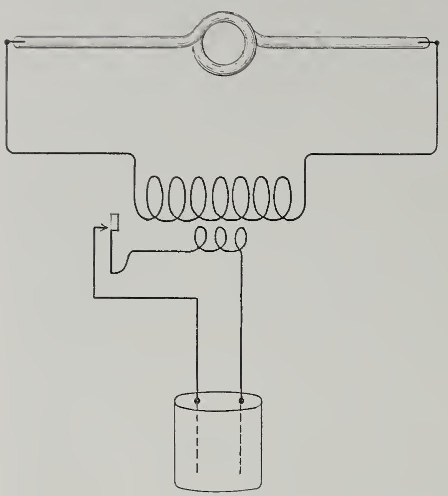


FIG. I.—A GEISSLER TUBE, SHOWING THE HIGH-POTENTIAL INDUCTION COIL TERMINALS ENTIRELY EXPOSED

velope of the electric arc—especially the so-called "flame-arcs"—has proven this, but such experiments with arcs are only very short steps in the right direction, compared with the proper utilisation of a long tube.

But now that an actual commercial start has been made, the final solution of this great problem, as theoretically indicated, will soon be reached and we shall have artificial daylight at least thirty times cheaper (not 30 per cent. cheaper—the gaseous conductor now found is about 30 per cent. cheaper than the incandescent lamp) than is possible with any means known at the present time. Electric lighting will then become the greatest of moral agents by invading the hovels of the poorest of mankind instead of being confined, as now, only to the homes of the well-to-do.

The solution of the problem necessitates the practical application of much of the intricate theory on electricity and the composition of matter in general that has been so freely discussed within the last few years.

Tube lamps of this character, especially when operated by alternating currents, which probably necessitate a re-ionisation of the gaseous conductor for each alternation, should have, theoretically, a life that is almost unlimited and already practice is bearing out this assumption in that a 50-foot tube has been operated for 1800 hours at a commercial brilliancy without any change detectable in either efficiency or colour. No "lamp renewals" are necessray when vacuum-tubes are used; neither are new carbons required every few hours as is the case with arc lamps.

Vacuum-tube lighting has come not only to stay, but to steadily grow until its use will be universal. It is the only form of artificial illumination of which the principles are correct. No argument should be needed to prove the general statement that the model or ideal light to be striven for is simply a reproduction of daylight—not direct sunlight—but diffused daylight. By reproduction is meant an imitation so accurate that it is difficult to determine whether an area is lighted by natural or artificial light. All other forms of illumination fall so far short of resembling daylight that a child easily detects the difference.

The incandescent lamp does not in any sense imitate daylight. There are three principal reasons for this:—The lamp is too small, too red, and too hot, and yet, the development of all forms of light, especially during the past twenty years, shows a positive tendency even with such poor means at command, to attempt with them to imitate daylight, first, by spacing small units in long rows; second, by striving to make the colour of the light approach a true white; and third, by endeavouring to reduce the heat.

The "spots" of light—arcs and incandescents—now in general use are merely "relics of barbarism," having descended to us from the torches of our savage ancestors. Surrounding a given area with, say, 100 spots of light, each one of which, like an incandescent lamp,

for instance, is made up of many parts, is in no way comparable, either theoretically or practically, with a simple straight tube consisting of but one element—the tube. Probably 75 per cent. of all the artificial light one sees in walking down a busy metropolitan thoroughfare at night is in rows of spots, and this fallacy of spots—not rows—clearly points the way for the new form of light—namely, one continuous tube of uniform brilliancy throughout its entire length, which length may be almost anything desired from a few inches to hundreds of feet and constituting a form of light radically different from the heretofore well-known systems.

Even the recent development of the arc lamp,—the most intense of light spots—has shown the evolution towards increasing the area of the source; that daylight, the tube has long been recognised by the greatest of scientists as possessing principles which some day might make it of extreme importance in the development of an artificial light far cheaper than any in use at present.

Tubes of much the same form as the artificial skylight referred to at the beginning of this article, but mounted in trunnions, are now in successful operation not only for the taking of the finest portrait photographs, but, by their light, artists also continue their work after the sun has set, and mix their colours as satisfactorily as in daylight.

Tubes of this general size and character are completed at the factory and simply erected in their final positions, but other installations have been made in which this diffusive idea has been followed out to such an extent that it

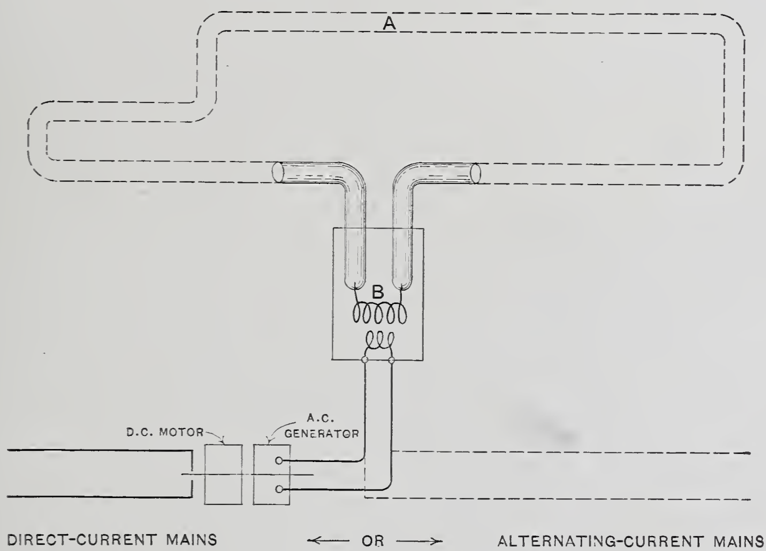


FIG. 2.—THE MOORE METHOD OF GUARDING THE HIGH-POTENTIAL CONNECTIONS.—AS THE TUBE *A* IS MADE LONGER, THE VOLTAGE AT *B* MUST BE MADE HIGHER TO CORRESPOND WITH IT

is, not only is the arc of an enclosed lamp longer than that of an open one, but the whole of the enclosing inner globe really becomes the source of light. It must, therefore, be granted that so far as the imitation of daylight is concerned, a long tube of light must be used. But, aside from the imitation of would be impossible, on account of the great length of the tube, to exhaust it at the factory and then ship it to its place of use. It thus became necessary to construct the tube upon the premises to be lighted.

The illustration on page 445 shows the first installation of this kind, located

A MOORE "PHOTOGRAPHIC WINDOW"

in the city of New York, consisting of one continuous tube 57 feet long and greatly varied in its form. In fact, it is probably the most elaborate piece of glass blowing ever constructed, yet it has been operating perfectly,—that is, without any change whatever,—for a number of months, and has proven, in a conclusive manner, that constructing very long tubes, by hermetically sealing together lengths that can be conveniently handled, is thoroughly practical.

The two ends of this tube are placed close together in a danger-proof steel box with only two low-potential wires extending into it from the alternating current source. A small transformer is also contained in this box. It thus appears that by utilising this simple danger-proof box idea an ideal system of illumination is evolved, yet one which involves in its construction, operation and maintenance only sound engineering principles. As seen by the illustration, this tube illuminates a large vestibule, and it was strikingly interesting last spring to note large icicles hanging from its exposed portion without interfering in any way with the operation of the tube.

In another installation of this kind the tube forms almost a plain rectangle as shown on page 449, but its distinctive feature compared with the other installations is that it is 154 feet long. No tube comparable with it in any way had ever before been constructed.

The amount of light emanating from each square inch of a vacuum-tube should not be large. Having in mind simply the artificial production of good daylight conditions, and an ordinary-sized room, the entire picture moulding of which is supplanted by a vacuum-tube, it has been found that such a room will be brilliantly lighted with a tube 2 inches in diameter at about 8 candle power per foot of length. With such a distribution of light, the extreme softness of diffused daylight is splendidly imitated.

The diffusion factor of the tube is almost perfect because 16 candle-power from a source 3 inches long (the incandescent lamp) does not produce nearly so good an illuminating effect as 16 candle-power from a source 3 or 4 feet long. The liability of breakage of a tube so placed is practically nil, and in first cost it can be made the cheapest form of lamp. Besides this, its decorative possibilities are unlimited and gaseous conductors can be found to give almost any colour desired. Cylinders of light now glow with impunity in the open and the struggle to conceal dazzling loops can end.

Other great changes are about to be wrought by these tubes. The endless array of elaborate chandeliers of the past and present will now also reach an end, since the new light, especially when arranged to meet architectural conditions is so perfect that it does not need them, either from a mechanical or an artistic standpoint.

Evolution has already shown, by the manner in which incandescent lamps have been used to light public halls, theatres and churches, in which the entire ceiling has been utilised as a fixture, that the pretentious electrolier is neither imperative nor desirable. Cumbersome and elaborate reflectors, now used so extensively in show windows and elsewhere, will be supplanted by a simple enamel coating on the back half of the tube.

These first commercial vacuum-tube installations represent simply the beginnings of a new large industry, since the underlying principles of this form of light are such that in its final development its field will be even greater than that now occupied by the incandescent lamp. They prove the general practicability of the whole scheme; nevertheless it should be mentioned that the difficulties met with in initial work of this character were enormous, requiring hundreds of inventions and extending from a new form of glass-blower's fire to the handling of the chemical under commercial conditions.

That this system of vacuum-tube lighting imitates daylight more closely than has ever before been done can not be questioned, and that the imitation of daylight should be the final goal admits of no argument. It is interesting to note that all forms of light since the beginning of the world have gradually drifted through evolution to this goal. Daylight has many characteristics different from artificial light, the most salient of which are diffusiveness, colour, absence of heat, efficiency, steadiness, safety, no vitiation of the atmosphere, simplicity, and life unlimited.

As to diffusiveness, it has already been pointed out that the improvement of the ages has consisted in the evolu-

tion of the torches of the ancients into rows of 4 or 8-candle power incandescent lamps, or the hideous diffusing reflectors on arc lamps.

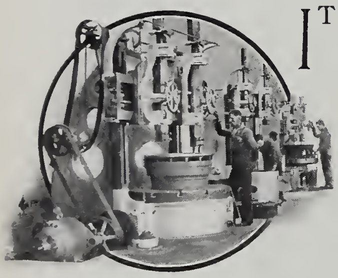
In colour, the improvement towards the white of daylight has advanced from the harsh red of the pine torch, to the tallow candle, the oil lamp, the gas jet, the incandescent lamp, and the arc lamp.

In the same way steadiness and safety have been improved, the heat has been reduced and the necessary apparatus has been minimised, and finally the vacuum-tube has surpassed them all in being a very real imitation of daylight.

This new form of light promises to be applied for all classes of illumination both indoor and out. Contiguous skyscrapers can now have daylight at their most remote interiors, and miles of continuous tubing will make perpetual daylight within the rapid transit tunnels of the Twentieth Century, and elevated railway structures in the streets of large cities will support at night continuous streaks of white light, extending under and over their entire lengths.

CHANGES IN MACHINE-TOOL DESIGN

By C. H. Benjamin



IT has been interesting to watch the changes brought about in the designs of machine tools as a result of the keen competition in manufacturing and the demand for a greater output per machine. Such a thing as running a lathe or a planer to the limit, even of its former capacity, was once a novelty. For the most part these machines jogged along in a comfortable and contented fashion with the operator also comfortable and contented.

The introduction of the new process steels for tools is a result rather than a cause of the recent awakening and of the endeavour to get out of each machine all that there is in it. Many of the tools built ten or twenty years ago were incapable of getting the best work or the limiting quantity from even the ordinary carbon tool-steels. The belt would slip, the gears would break and the frames and spindles would spring.

Of late, however, machines weigh more, have wider belts, bearings of greater surface, and can stand up to the work required of them. But now comes the high-speed steel and there is more trouble. Not only must the machine have stronger parts, but it must have more power to turn the spindle and to push the carriage. To understand this, it is only necessary to make a few comparisons.

Formerly the lathes, planers, shapers and other tools in an ordinary machine shop consumed from half a horse-power to two horse-power each. The writer has seen a 16-inch lathe stalled when doing less than one horse-power.

Recent tests with a lathe of 20 inches swing, turning soft steel, have shown a gross horse-power of from seven to sixteen with one maximum reading of over thirty horse-power. The manufacturer of one well-known turret lathe recently told the writer that a new machine now building for use with high-speed steels would consume twelve horse power. This will be more easily understood when we consider the enormous amount of metal removed by some of the new machines.

One lathe, when turning soft steel at a speed of 125 feet per minute, removed metal at the rate of 625 cubic inches per

minute or about 1000 pounds per hour. Another lathe, running three tools, cut steel with a speed of 50 feet per minute at the rate of 113 cubic inches per minute or about 1900 pounds per hour.

A prominent firm making slab milling machines, guarantee the removal of 210 cubic inches of cast-iron per minute, or about 3200 pounds per hour.

Now reliable tests of machines in actual service show a consumption of power per pound of metal per hour of 0.03 to 0.07 horse-power under favourable conditions, exclusive of the power required to run the machine itself. Using the smaller value. or 0.03 horse-power, gives the power required in these three instances as 30, 57 and 96 horse-power, respectively.

The cases cited are, of course, extreme ones and examples of what may be called "slaughtering stock," but they nevertheless show what these machines are capable of doing. The rapid reduction lathes, as they are sometimes called, present several points of difference from their immediate predecessors. The steps of the driving cone are fewer in number and have faces suitable for wide belts, sometimes four and sometimes even six inches wide. The speed of the belt is also increased, for it is an axiom that the power of a machine must be measured by the belt and not by the gearing. No complication of double or triple gearing will give power to a lathe which has a narrow, sluggish belt.

Cut spur gears are now used wherever necessary and gear boxes have taken the place of speed cones for controlling the travel of the tool. The mechanism inside the apron has received particular attention, for this is the weak point of many lathes. The use of steel gears and racks and of double bearings for the pinions has remedied this defect.

The tool-post has been strengthened, the head and tail spindles have been enlarged and all the bearings are made wider and longer. Some of these lathes are now capable of melting the points from the new steel tools.

It is rather remarkable that the principal advantage in using high-speed steel has appeared in the turning of wrought iron and mild steel and that cast iron still remains obdurate. While it is no uncommon thing to-day to see soft steel turned at speed varying from 125 to 250 feet per minute, a speed of over 50 to 60 feet per minute for cast iron is unusual. The peculiar granular character of the casting or perhaps the presence of graphite is fatal to the life of the tool point at high-speeds.

Planing machines have not profited by high-speeds as have the lathes, probably on account of the intermittent character of the work. Sixty feet per minute are about the highest recorded speed, and this is not recommended for ordinary planing. A cutting speed of 35 feet per minute with a return of two to one is as high as can be economically used. A common mistake which has been made is to increase the return at the same rate as the cutting speed. This is apt to make trouble at the end of the return stroke.

The possibility of doubling the cutting speed without changing the return is excuse enough for the use of the new steel. A good arrangement adopted by our planing machine builder company is to vary the cutting speed from 20 to 40 feet per minute by gears and to keep a constant return of 72 feet per minute.

The power required for reversing a planing machine is so much greater than that ordinarily used in cutting metal, that an increase in the latter, due to the use of high-speed steels, has not materially affected the driving power required. What is generally needed is not so much power as fly-wheel effect.

Some rather remarkable records have lately been made with twist drills of the new steel, but in Great Britain, rather than in America.

The cutting speed of the lip of an ordinary carbon-steel drill has usually been from 25 to 35 feet per minute. With the new drills these speeds have been more than doubled, with compounding increase of the feed and an even greater difference in the total number of inches drilled. This means a stiffer machine, more belt power and the use of positively geared feeds.

The milling machine is beginning to

feel the new influence, and both speeds and feeds are being increased, more particularly the latter. A feed of two or three inches per minute used to be considered good practice. To-day ten or even fifteen inches per minute are not excessive for the travel of the table.

Experience has shown that increasing the feed is more profitable than speeding up the cutter. The principal changes that are noticeable as a result of the new practice are a strengthening and stiffening of the support for the cutter arbour and a substitution of geared for belted feed motions.

It is to be noted, however, that the increase in power required with the new steels is not so great as the increase in output secured. There are numerous instances where the work done has been more than doubled, while the power increase required has not been more than 50 per cent. The average consumption of power by carbon steels is usually 0.05 or 0.06 horse-power per pound of metal removed per hour, and the new steel will require only 0.03 or 0.04 horse-power.

The increasing use of electric motors is, or should be, a factor in the development of machine design. Except in a very few instances, however, little modification has been made in adapting machine tools to the new motive power. In most cases the change has meant a bracket cast or bolted to some convenient part of the frame and the connection of the motor by belt, gears, or chain to the driving mechanism; in other words, merely substituting the motor for a counter-shaft.

At the present time there is no standard type of motor for such service, and most tool builders are advertising their willingness to adapt their machines in a tentative way to whatever motor the customer may elect.

In many shops the group system of driving is the more economical, and no modifications of the machines themselves are necessary. But even when its independent drive is decided upon, there is no unanimity of opinion as to how it shall be arranged. Some prefer the variable-speed motor with a controller, some the smaller constant-speed motor with mechanical speed control, and some a combination of the two.

One designer uses belts, another gearing, and a third the silent chain; in fact, most builders advertise all three, leaving the burden of choice upon the buyer. Perhaps the general consensus of opinion is in favour of the costant speed motor, as it is smaller and cheaper and can be run at a high speed.

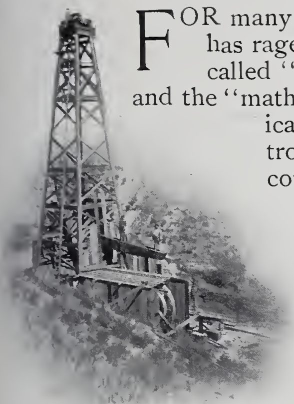
On large machines where a considerable range of speeds is economical, a combination of the two systems is desirable, using perhaps four to six speeds on the controller and multiplying these by the usual gearing. Some large lathes and boring mills have as many as 72 speeds obtained in this way.

It is evident to the unprejudiced observer, as he studies the various arrangements of motor drives shown in catalogues, that the machine tool builder and the electrician have not "got together" on this problem, and that in most instances the machine has not been adapted to the motor or the motor to the machine. There is some excuse for this in the fact that most manufacturers of machine tools build certain standard machines which are to be sold to the trade and are to be driven, some in the old and some in the new way, and must consequently be adapted to either set of conditions.

The rapidly increasing use of electricity as a motive power will change all this, and every year more machines will be built for electric drives alone. We shall then see machine tools in which the motors will be an integral part of the design and the present loose and temporary relations will be replaced by a definite and permanent connection.

MATHEMATICS IN ENGINEERING

By Thorburn Reid



FOR many years a controversy has raged between the so-called "practical engineer" and the "mathematical or theoretical engineer," a controversy which has its counterpart in many other branches of professional as well as business life and is intimately connected with the question of the value or worthlessness of a college education to the man who has his way to make in the world.

Some one, I think it was that original mathematical genius, Oliver Heaviside, who was wont to scatter mirth-provoking witticisms at rare intervals through the pages of his most abstruse mathematical treatises, once coined the term "practician" to designate the man who despised mathematics and theory and worked by experience and "rule of thumb." The word avoids some circumlocution and has a definite meaning and I shall, therefore, use it in what follows. Also, if I may be allowed to coin a new word myself, or rather to extend the meaning of the old one to a class to which it has not commonly been applied (which was in reality what Heaviside did), I shall use the word "precisian" to denote the mathematical or theoretical engineer.

The question, then, is not "is mathematics useless?" for no sensible man would ask any such question regarding mathematics when confined to its own proper sphere, but "is mathematics of value to the practical working engineer who must accomplish actual, useful results—who must do things?" The question has so far been approached very largely from the empirical side; the "practician" has cited numerous cases coming under his observation where the use of mathematics has resulted in failure or disaster and the "precisian" has cited cases where the use of the rule of thumb method or the lack of mathematics has led to the same result. Such reasoning, however, can apply only to the experience of the man who employs it and should obviously not be used to formulate a general law, especially when it is remembered that human nature is prone to see only those facts which chime in with preconceived ideas. A study of the nature and use of mathematics, in connection with engineering problems at least, will serve to show even more clearly to what fallacious results such reasoning may lead.

The practician's idea of the nature and use of mathematics was once well expressed by Mr. T. D. Lockwood, in a comment he made on a very mathematical paper read before the American Institute of Electrical Engineers, when he said:

"Mathematics, however valuable it is (and no one can doubt its value if properly used), is too frequently like a very well fitted and extremely costly machine shop, filled with the highest order of machine tools, owned and operated by some person who, with all the necessary skill to work them, employs his skill and the time of the machine's in doing nothing else but making more machines of a still more costly and intricate nature."

Mathematics, as Mr. Lockwood so neatly puts it, does consist of fine, accurate tools, but these tools must be used by workmen who are experts in managing them or the job will inevitably be spoiled.

It has also been described as a language that must be learned, but the writer has always preferred to call it "short hand reasoning." According to this conception the letters and symbols used in mathematical analysis are simply abbreviations for words and phrases, just as the pot hooks of stenography are abbreviations for words, sounds and, in some cases, phrases.

The principles upon which the processes are based by which these letters and symbols are combined into equations and by which the equations are solved in order to reach a correct conclusion from the data supplied, are the ordinary principles of human reasoning; that is, reasoning from cause to effect or from effect to cause, just as in stenography the words represented by characters are combined into sentences in accordance with the laws of grammar and the usages of common speech. But stenography, as well as mathematics, is a useless tool to the man who has not studied it and become expert in working with it.

Much of the prejudice existing among practicians against mathematics is caused by the mathematicians themseves and especially by those of them who teach mathematics. Unlike the stenographers, however, they unconsciously grow to think of the solution of a problem, not as a means to an end, as they should, but as the end itself. It is natural, perhaps even inevitable, that this condition should continue, at least to a very large extent, for the reason that for the teacher as well as the student the solution of the problem is usually as far as he can go and it is seldom that either of them has an opportunity to observe a practical application of the results obtained or to check them by comparison with the results of tests.

Another very serious defect in prevailing methods of teaching and a defect that seems as inevitable as the one mentioned is the custom of giving the student his data in numerals, all neatly arranged for insertion into equations.

These two defects militate strongly against the practical use of mathematical analysis in two widely different ways. The latter often leaves the novice helpless to apply to practical problems the knowledge he has gained; the former leads to costly and disastrous mistakes which discourage him from again attempting to use the same means.

Imagine the average graduate of a technical college, standing, say, on the top of some river-side cliffs, asked to determine roughly and without other instruments than a two-foot rule and a watch the width of the river at that point, a problem which was put to the writer as a boy and easily solved mainly because of previous training in determining the heights of trees and other similar problems by triangulation. I moved back from the edge of the cliff until my eyes, the cliff edge and the opposite shore of the river were in line, and measured the distance from the cliff edge to where I was standing and the height of my eyes above the ground. I then threw stones out as nearly horizontally as possibly, noted the time required for them to reach the surface of the river and calculated from that the height of the cliff above the river; the rest was a simple solution of similar triangles, which gave a result surprisingly nearly correct, considering the exceeding inaccuracy of the means at hand for making measurements.

The ordinary way in which such a problem would be given to a student would be something like this:—

"A man stands on a cliff overlooking a river, with his eyes, the cliff edge and the opposite bank of the river in line, his feet being on the same horizontal plane with the cliff edge. He stands so many feet back from the edge of the cliff, his eyes are so many feet above the ground and the height of the cliff is so many feet; what is the width of the river?" The hardest part of the problem, the only part in fact that presents any difficuty, is solved for him beforehand.

It has certainly been my experience, and I think every engineer who is at home in the use of mathematics will agree with me, that by far the greatest difficulty lies in formulating a basis for analysis; that is, in determining what

data can be ascertained by tests or measurement to serve as a basis for analysis. Usually when this has been properly done, the problem may be considered as solved and in this branch of the subject the student, as a rule, gets little or no practice or instruction.

The same example may serve to illustrate the other defect mentioned. The student seldom has a chance to connect the numbers, figures, and symbols with the actual measurements and objects they represent. To him they have no concrete meaning except as symbols and figures and to use his solution practically, as, for instance, in determining how long it will take him to row across a river is an idea that is often new and strange.

Further, he has no idea how far he can trust the results of his analysis, has had little training in judging the accuracy of his data, since in the main they are given to him cut and dried, and he is thus apt to consider his results as accurate as are the processes by which alone he has arrived at them and he, consequently, often acts on this conclusion with disastrous results.

I am not here concerned with the remedies of such defects in teaching nor with the defects themselves, except in so far as they throw a side light on the subject under consideration by showing not what is the proper sphere of mathematics in engineering, but why so many engineers feel that they have no place in it at all. It may be also well to add that I do not hold these defects in teaching to be universal, but that they are the rule, although there are doubtless many shining exceptions.

The problems confronting the engineer involving the use of mathematical analysis or formula may be roughly separated into two classes,—those which do and those which do not involve original investigation.

Few engineers are called upon to attack problems of the former class and fewer still are capable of solving such problems. The use of mathematics is generally unavoidable in such cases, unless the engineer be that rare genius,—the natural mathematician.

Some one defined genius as "infinite capacity for taking pains." Like most such epigrammatic statements, it is but half the truth. Without some special aptitude for the work in hand no amount of painstaking labour will avail to accomplish the results that lift the genius high above his fellows.

Inventors often are natural mathematicians, that is, they are able to solve the problems that arise by attending directly to the elements of the problem itself without recourse to mathematics, and the clear and luminous picture they are thus able to form in their minds of the interrelations of all the various factors affecting the problem enables them to predict effects and accomplish results astounding to the plodding mathematician who follows slowly and laboriously in their footsteps.

As an example of this faculty, Mr. Wm. Stanley, Jr., once asked the writer to solve mathematically a problem whose solution would be expressed as a curve. The long and intricate analysis covered several sheets of paper with cabalistic symbols, signs and equations, and before it was finished Mr. Stanley came in and asked if I had reached any result. I replied that my analysis gave the curve as a straight line, but that I would have to check up the work before being sure of its correctness. He said, with perfect confidence, "That is wrong," and, without any hesitation or calculation, he drew with a pencil a curve on a sheet of section paper and said "That will be about right." I checked over my work, found a mistake and corrected it, and saw that the values given by the correct equation differed scarcely ten per cent. from the curve Stanley had drawn.

As an example of this same faculty in the case of an eminent engineer, rather than an inventor, Mr. H. F. Parshall once instructed me to design an alternating-current generator whose size and speed differed widely from anything we had previously designed or made. When I had finished the design, I took it to him and merely detailed its general features and the methods of calculation and then took it to the cost department

for an estimate of cost. The result so surprised both myself and the head of the cost department that we went back to Parshall, and without telling him what we had found asked him what he thought it should cost. He turned and looked out of the window a moment, then answered "eight dollars a kilowatt." We had it eight dollars and three cents a kilowatt.

Of course so close an agreement as this was a mere coincidence, but it was only one of many instances where his apparent guesses were practically as accurate as the results of detailed calculations.

Both of these examples might seem at first sight to be arguments against the use of mathematics even in original investigations, but it must be remembered first that genius, of the order possessed by these two men, is given to few engineers, and secondly, they both recognized the necessity of having their conclusions verified by the certainty and accuracy of mathematical methods.

The ordinary engineer, who is not a genius, must either use mathematics in problems of this class or must employ the slower and usually much more costly methods of trial and failure.

On the other hand, the novice in attacking such problems is apt to rely too much on the results of his analysis. It is never possible to have absolutely accurate data on which to base an analysis and, what is far more important, it is seldom possible to take account of every factor that may affect the result.

This latter is an especially frequent and insidious source of error when mathematical analysis is employed for the reason indicated, that the mind is taken away from the actual physical facts of the case and concentrated upon the symbols employed and upon the means of solving the equations. For this reason the only safe way to avoid such errors is to refer back every important equation reached in the course of the analysis to the physical facts it represents. In other words, retranslate into words the symbols of the equations and see if the law or fact it represents is a reasonable deduction from the premises, whether the inaccuracy of the data or the omission of certain factors of the problem, which at the beginning of the investigation seemed unimportant, might not at some stage of the analysis be found to have a much greater bearing on the result than appeared probable at the start. Such a practice also serves the important purpose of bringing to light errors in the processes of the analysis itself.

In fact, no important original engineering work should be based on such analysis unless it be possible to follow through the whole line of reasoning represented by the analysis. This thought relegates mathematical analysis to what is its proper sphere in such investigations, that is, its mechanical processes are a powerful instrument for directing the mind into the correct line of reasoning and when reasoning, following the steps of the analysis, has shown it to be correct, the final equations can be used to furnish exact numerical values or quantitative laws.

This apparent lack of confidence in the results of such analysis is not because its processes are not perfectly exact or because there need be any great probability of error, for neither of these things is true, but because nature does not provide material objects formed with the same exactness as are their imaginary representatives in mathematical analysis, and for the far more important reason that even with the use of every available aid toward the predetermination of final results, it is almost impossible in original work to think of and allow for the effect of every factor that may enter the problem and affect the final result.

An equation based on certain assumptions will, if the analysis be correct, be an exact statement of what will result if conditions are in strict accordance with those assumptions, and if they include all the factors affecting the result; but it gives absolutely no information as to the accuracy or completeness of the assumptions themselves unless it, as well as the steps leading up to it, be referred back to the physical conditions it represents. That is, while the analysis itself is an absolutely exact process, the as-

sumptions on which it is based can never, in the nature of things, be exact, but must always be more or less approximate representations of the actual conditions. It is this limitation that must be always kept in mind by the engineer who is engaged in original research if he wishes to avoid humilitaing and often costly mistakes.

When the pure mathematician who is without practical engineering experience has finished his analysis, he is apt to consider his task ended, his goal achieved, since he usually has neither the data necessary to check his results nor facilities for testing them by experiment. The engineer, however, if he be wise, will compare his results with facts, if he has them, or, if not, will, if possible, make experiments to determine the accuracy of his deductions before relying on them in any important engineering work.

I was once discussing with Dr. C. P. Steinmetz, one of the foremost mathematical electrical engineers, the results of a mathematical investigation he had been making. I stated that his equations did not agree with some facts brought out by experiments that I had made.

He promptly replied "If the facts do not agree with my equations, the facts are wrong."

This paradox seems at first sight to run directly counter to what I have just been saying, but it is really an inverted application of exactly the same principles. The thought in his mind was doubtless, "My equations are correct deductions from the assumptions I made. If your facts do not agree with my equations, then the conditions under which the experiments were made were not such as I assumed for my analysis."

Engineers who know his achievements will, without dissent, accord to Dr. Steinmetz the privilege of expressing such confidence in his deductions, as was shown by their acceptance without comment of a statement made by him in his paper read before the American Institute of Electrical Engineers in which he disclosed his celebrated one and six-tenths power law of magnetic hysteresis. This law was admittedly entirely empirical, a large number of tests having been made, and the results plotted in the form of curves. A number of different equations were then tried until one was found that gave curves agreeing closely with those obtained by test, the two sets of curves being plotted on the same sheet, to show the closeness of their agreement.

Steinmetz then said that if any value was found to be very much out of the curve connecting the other values, it was stricken out as evidently erroneous, not considering it worth while to determine whether it was wrong reading of any one of the instruments or a mistake in the calculation. Such a statement coming from an ordinary engineer would have been considered as tantamount to saying, "I picked out such points as confirmed the practical accuracy of my equation and discarded the rest," thus basing the equation on the points and then the points on the equation. Doubtless the engineers present felt that Steinmetz reasoned justly that the curve of hysteresis was a smooth one and that, if a point here and there was considerably off the curve drawn through the other points, the probabilities were so overwhelmingly in favour of an error in the readings that it was not worth while to repeat the tests to detect the error, all of which only goes to show that the master is not subject to the same limitations as are his disciples.

This law first disclosed by Steinmetz has since been tested probably thousands of times and found to be accurate enough for most purposes, and this leads us to the second class of problems which the engineer is called upon to solve,—those which do not involve original investigation but rather the application of equations previously deduced by original investigation and subsequently tested and found sufficiently accurate for the ordinary purposes of the engineer.

It is in this field that the battle between the precisian and the practician is mainly waged, and, as in most such controversies, the greater part of the fighting is futile and beside the mark.

Lawyers, whose profession is pre-

eminently the practice of controversy, have a process technically called "special pleading" the function of which is the elimination from the discussion of all considerations which are irrelevant or immaterial, and a clear unmistakeable definition of the exact question at issue. This process is a wonderful time and labour saver and can, with great advantage, be applied to all controversies whether legal or not. In fact, such a clear statement of the question at issue often decides it without further controversy.

In order to define the question at issue between the practician and the precisian in regard to the utility of mathematics in engineering, we must first understand clearly what the engineer wishes to accomplish; and, second, the means by which he attains his ends.

The main purpose of the engineer's labour is the production of structures of material utility to mankind by a combination of the properties of the materials of nature that are at his disposal.

The engineer with his mind centred on the objects themselves is often unconscious of the fact that it is not primarily these objects, but rather their properties, which he employs. Each material of construction is to the engineer in reality but a bundle of properties which can not be dissevered. Some of these properties are useful for his purpose, some are useless or even detrimental, but all, whether useful or detrimental, must enter into the combination of which the material to which they belong forms a part. The engineer, then, who possesses the most complete and accurate knowledge of the properties of the materials he must employ, has the most ample resources and can employ them with the greatest precision. There can be no controversy as to this statement nor as to the further statement that, other things being equal, he is the best engineer who possesses the most ample resources and the most accurate knowledge of the properties of materials.

In order that this knowledge may be used to the best advantage, it should be in such shape as to be quickly and easily applicable to the solution of the problems in hand. The more quickly and easily this knowledge can be applied, or, to put it a little differently, the more of this kind of knowledge the engineer has, which is quickly and easily applicable, the better.

The engineer may have certain qualities of mind, of temperament, or of character which have a much more important effect on his efficiency as an engineer than the amount of availability of the knowledge he possesses; but with these we are not at present concerned, except in so far as his methods of work may possibly have a modifying effect on such qualities. On the contrary we are concerned with the knowledge he possesses and with the methods of his application of that knowledge in his work. The more complete and accurate this knowledge of the properties of materials is, the better, as a consideration of the form of this knowledge will make clearer.

Most of these properties must be expressed quantitatively. Strength, cohesion, friction, weight, heat, or electrical conductivitity and many other properties are expressed by numbers. The so-called laws of nature, which are, in reality, but statements of properties of matter, are not however stated in numbers simply, but as relations existing between two or more properties of matter.

Now, if these numerical values expressing the degree of strength, weight, etc., which are properties of a particular material, are used in engineering work, a certain amount of calculation is necessary, and if the relation existing between the properties of matter are to be used, they must be expressed in formulæ, whether the quantities entering the formula are represented by words or by symbols. Here is the crucial point of the controversy. The practician contends that his judgment, trained by long experience, will enable him, in many instances at least, by mere inspection to approximate more closely and surely the correct proportions than will the elaborate calculations of the precisian.

The precisian contends, on the contrary, that there are no instances, or at

most very few, where more precise methods will not give better results.

There can be no controversy, however, as to the fundamental thesis that, provided all the factors affecting the work in hand are taken into account, provided the constants on which the calculations are based are reasonably accurate and proper allowance be made for their inaccuracy, and provided no mistakes are made in the calculations, more accurate proportions will result than could be attained by the use of the best trained judgment by mere inspection. This is to say that the methods of the precisian, properly used, produce more accurate and efficient proportions than do those of the practician also properly used.

As to whether there is any property inherent in the methods of the precisian that militates against their proper use to such an extent as to make them less accurate and reliable than the methods of the practician, I am not here concerned, but I may perhaps be pardoned if I turn aside to point out one fallacy in the common argument on this point. This argument is that the precisian makes more mistakes than does the practician, and that, therefore, the methods of the precisian make him more liable to err.

Statistics have been grossly libelled as being notorious liars. It is not the statistics that are liars, but the people who draw improper or unwarranted inferences from them. Admitting, for the sake of argument only, that the precisian makes more mistakes than does the practician, it does not by any means necessarily follow that his methods must be made to shoulder the responsibility, for there is another possible explanation of the fact, if fact it be, and one that is more inherently probable; that is, that the class of mind that naturally tends towards the use of mathematics in engineering is apt to lack certain qualities essential for success in practical work; but this is entirely aside from the value of the method itself and is a question only of the efficiency of the man.

It is at least possible, even probable, that most precisians would be poorer engineers without their mathematics and that facility in the use of mathematics would increase the usefulness and efficiency of the practician. Since there are thus two possible inferences to be drawn, and since it is not feasible in practice to separate the method from the man, the question as to which of these two inferences is correct can not be decided by two contrasted methods, and this article may be considered as an attempt to clear up one field of the controversy by defining the sphere of mathematics in engineering and by pointing out certain sources of error which should be avoided.

I have said that precise methods, properly used, produce more accurate and efficient proportions than can be attained without them, but such accuracy is sometimes of minor importance as compared with other considerations entering the situation. A story is told of Captain Mason, chief of construction in the Confederate Army under General "Stonewall" Jackson, that he was once ordered to build a bridge over a certain stream just as soon as it could possibly be done and that plans would be furnished him by the engineers in a day or so. A few days later General Jackson asked him if he had received the plans for the bridge.

"No, sir," replied the grizzled veteran, "I've seen none of their pictures, but I've built the bridge and you can cross it when you are ready."

That was clearly a case where the engineer's calculations were out of place, as the bridge was amply strong for its purpose, probably much stronger than was at all necessary; but under such conditions economy was a minor consideration, while speed was all important. It is probable that Captain Mason could have built as good a bridge in the same or even less time if he had possessed in addition to his long experience as a practical bridge builder the ability of a trained mathematician and the bridge would doubtless have been built with less material and in less time if the engineer's plans for it had been immediately available.

The main advantage of formulæ in

such problems lies in their certainty and exactness as compared with the best of guess work commonly called rule-of-thumb; but these formulæ must be used with judgment and especially with understanding. It will not do to go to some engineer's hand book, extract a formula that seems to fit the case and, applying it to the case in hand, use the values it gives, blindly and without understanding. This is to court disaster, for, while correct results may be attained by good luck, sooner or later a mistake will occur. The formula itself, as well as its method of derivation and the assumptions on which it is based, must be understood. This does not mean that the engineer must be capable of deriving the formula or even of understanding the mathematical processes by which it was derived, but he must understand the reasoning those processes represent, for it is only thus that he can understand the reasons for the presence of the various factors the formula contains and be in a position to allow for other factors which may affect the problem in hand and not be present in the formula.

Consider, for instance, the formulæ for falling bodies given in most handbooks. There is usually no mention of the resistance of the air as affecting their accuracy and yet, if the stone I threw off the cliff top, mentioned earlier in this article, had fallen a few thousand feet instead of a few hundred, or if a light piece of wood had been thrown instead of a stone, the air resistance would have made a serious error in the calculated height of the cliff. A knowledge of the fact that these equations were derived from the observation of bodies falling in a vacuum would be a safeguard against errors of this kind.

Nothing will guard against such errors except a complete understanding of the formula and of the assumptions and principles upon which it is based. The engineer can otherwise do no better work with them than could an unskilled labourer with machine tools. He must know his tool, its ins and outs, the interrelation of its parts and the function each part performs toward the final result

Further, he must consider the reasonableness of the values the formula gives. It sometimes happens that a formula which is sufficiently accurate over the range of values ordinarily found in practice will yield wildly inaccurate results in extreme cases; or the engineer may forget that some factor affecting the problem in hand is not included in the formula and this points to another liability of error that is inherent in the use of mathematics, already noted in connection with problems involving original investigation,—the mind is taken off the realities of the case, the actual materials used, and the conditions to be met, and is concentrated upon symbols and signs which give no indication of the correctness of the results obtained.

In order to minimise the liability to error from this cause the engineer should compare the proportions thus obtained with those which his judgement, trained by experience, would lead him to expect, and if the two differ widely, he would be wise, if he has the time, to trust to the correctness of neither conclusion until he has reasoned out why they differ and thus determined which is in error.

To sum up then, mathematical analysis can not with safety be used by the engineer who has not been trained to its use in practical work. Even then he must not rely too much on the results obtained by its processes, but must continually refer back its conclusions to the physical facts they represent. In other words the processes of mathematics are not to be used to supplant his reasoning, his common sense, his trained judgment, but to aid these by broadening his resources and increasing the accuracy of the knowledge which his other powers of mind will thus enable him to use to better effect.

While I had no plan in writing this to contribute anything to the controversy between the practician and the precisian, yet the position to which I have relegated the use of mathematics in engineering should, if it be accepted as the proper one, go far towards apportioning to each side the moiety of right belonging to it by indicating when the use of mathematics in engineering work is proper and when it is improper.

THE MOST POWERFUL LOCOMOTIVE IN THE WORLD

By George W. Martin

THE Baltimore & Ohio Railroad, one of the most go-ahead railways in the United States, has always been to the fore in respect to locomotive novelties, to which fact the historical collection of actual engines and small scale models now on exhibition at St. Louis bears ample witness; and the latest design adopted for mountain service most effectively heads the list of locomotives owned by the company, for it is, without any question, not only the biggest locomotive yet built, but it is also the most powerful in existence, and it is, besides, of a type unique in America.

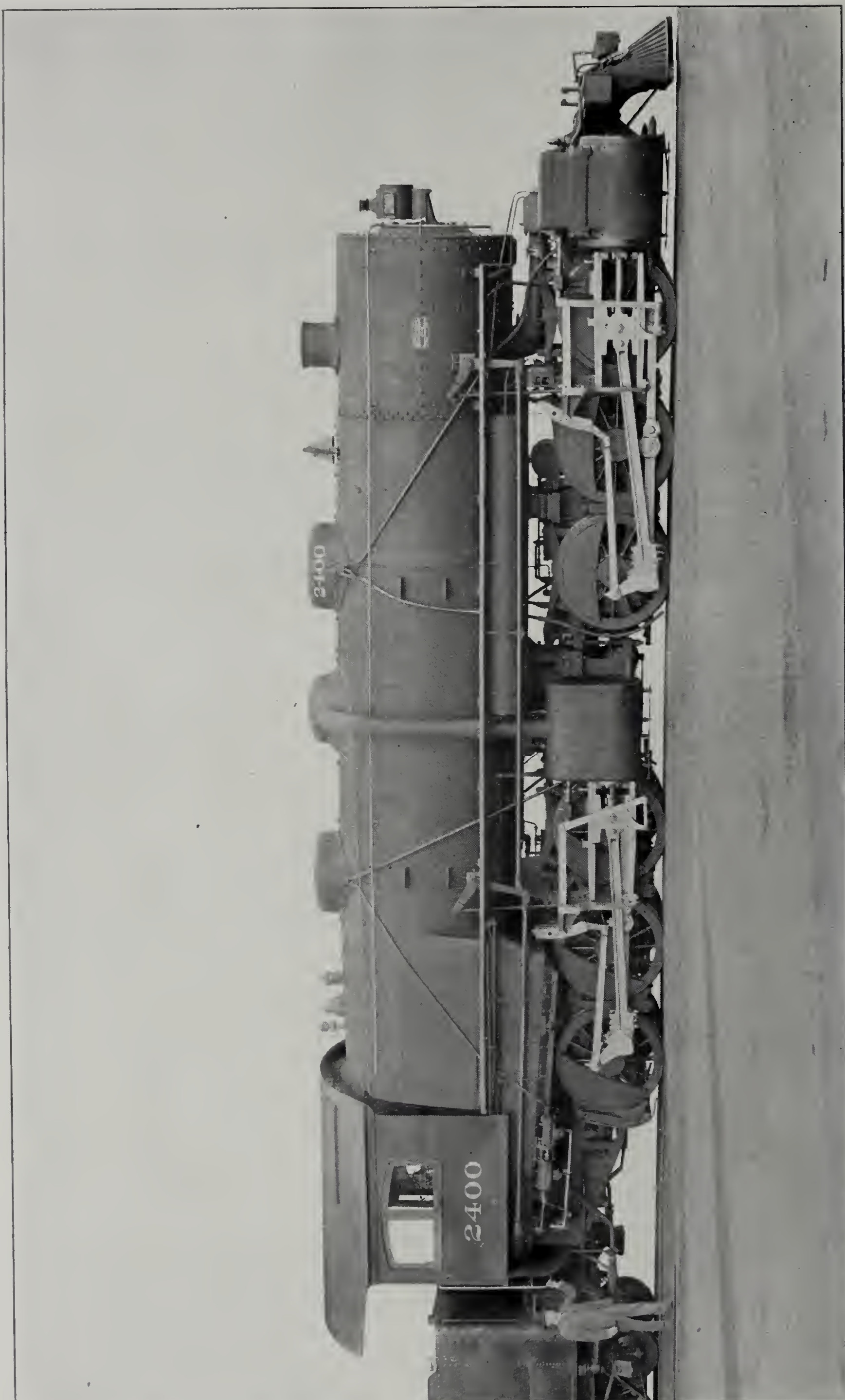
In comparing the power of locomotives of different types, probably the best method for general purposes is to consider the weight available for adhesion, as this is a matter which has a close relation to the power which, put into the engine in the cylinders, is given out at the wheels.

The world's record in locomotive power has been credited, prior to the appearance of the Baltimore & Ohio engine, to the enormous tandem compound ten-coupler engines built last year at the Baldwin Works, Philadelphia, for the Atchison, Topeka & Santa Fé Railroad. These engines have a total weight of 128¼ tons (without tender) of which 104½ tons are available for adhesion, the remainder being carried by the leading and trailing carrying axles.

Strictly speaking, this is surpassed by the " Shay " locomotives of the El Paso Rock Island Railway (see CASSIER'S MAGAZINE, December, 1903, page 129) which have a total weight, all used for adhesion, of 130 tons; but as, to obtain this, the weight of the tender is included, the comparison, though interesting, is hardly relevant to the subject now under consideration.

The new Baltimore & Ohio engine, shown in the accompanying illustration, far exceeds either of these, for the engine alone, without tender, weighs 149¼ tons, all of which is utilised for adhesion, as all the wheels are drivers. This engine, which is now at the St. Louis exhibition, has been built at the Schenectady Works of the American Locomotive Company, and is intended for service on the mountain section of the Baltimore & Ohio Railroad, to obviate, as far as possible, the use of " pushing " and " banking " engines for heavy freight trains on the steep gradients.

Apart from its dimensions, the engine is also noteworthy as being the first engine in the United States to be compounded on the " Mallet " system, though there are hundreds of engines of that type, large and small, now in use on various European railways. Some of these " Mallet " engines were described by the writer in the February, 1904, number of this magazine. Essentially, the Mallet system of compounding, as applied to articulated locomotives, consists in the employment of two high-pressure cylinders driving one set of



THE MOST POWERFUL LOCOMOTIVE IN THE WORLD. BUILT FOR THE BALTIMORE & OHIO RAILROAD AT THE SCHENECTADY, N. Y., SHOPS OF THE AMERICAN LOCOMOTIVE COMPANY

coupled wheels and carried by the main frames, and in the use of two low-pressure cylinders for driving another set of coupled wheels, these cylinders and wheels being mounted in a pivoted bogie frame. In the American engine there are two sets of six-coupled wheels, making twelve driving wheels in all. The engine is, moreover, nearly twice as large as any "Mallet" engine previously built.

Engines with twelve driving wheels arranged in two sets of six, are not unique in American practice, and even engines with tender coupled wheels are not unknown; but arranged in the "Mallet" fashion, the type is quite new to the United States.

The cylinders of this huge engine have the following diameters: high-pressure, 20 inches; low-pressure, 32 inches; stroke, 32 inches. The wheels are 56 inches in diameter, and the coupled wheel base—the actual right wheel base of the engine—is only 10 feet, though the total wheelbase is 30 feet 8 inches. The high-pressure cylinders are supplied from the boiler in the usual way, but, owing to the low-pressure cylinders being arranged on a pivotally arranged truck, a flexibly converted receiver pipe is employed between the high and the low-pressure cylinders. The boiler pressure is 235 pounds to the square inch, but as the receiver pipe is subjected to a pressure of only about 60 pounds per square inch, it is easy to make the joints steam tight. A separate exhaust valve, similar to that used for the Richmond two-cylinder compound locomotive, is fitted to the high-pressure cylinders, while boiler steam can be admitted to the low-pressure cylinders through a reducing valve for starting or when extreme power is required.

The valve gear is that known as the "Walchaert," a gear which is greatly favoured on the European continent though it is not used largely in Great Britain or America. It was adopted in the present instance owing to the fact that all its parts are outside the driving wheels, leaving the space between the frames available for the receiver pipes and other parts.

The engine is reversed and the cut off regulated by a compressed air reversing apparatus, designed by Mr. Carl J. Mellin, who was the engineer in charge of the design of this locomotive. This power reversing gear has worked very satisfactorily, and it will be of great help in reducing the work required by a locomotive engineer in handling this immensely powerful machine. The tender, and a large part of the details of the locomotive, are Baltimore & Ohio standard, and the engine will be used on the Baltimore & Ohio for pushing service on the heavy grades.

The locomotive has been designed with great care, with a view to maximum durability, and freedom from breakdowns, and it is noteworthy that it was finished complete without a hitch or interference of any part with another, the design working out exactly as planned in every respect. The weight distribution especially is exceedingly satisfactory, there being a difference of only 900 pounds between the weights on the back and front sets of driving wheels. Considering the fact that no locomotive of any such size has ever been built, and that the design was practically new throughout, this statement shows the great accuracy of the calculations made.

Notwithstanding the immense weight and power of this locomotive, the fact that the driving wheels and cylinders are divided into two sets enables the parts to be made of ample strength, and yet with reasonable weight, the connecting rods, crossheads, and all parts of the valve gear being considerably lighter than those used on many of the heavy locomotives of the ordinary type.

In case the machinery in connection with one set of driving wheels becomes disabled, the locomotive could be run at one-half its power with the remaining set, and the change in this respect could be accomplished with very little difficulty, and by a locomotive engineer on the road.

Before being sent to St. Louis, the engine was subjected to a series of trials on the grade of the New York Central Railroad at Schenectady, and these trials, besides being satisfactory in other

respects, gave very good results as regards economy in fuel consumption, in view of the immense tractive power obtained.

A few of the leading dimensions, including those already mentioned, are given below, from which it will be seen that in all respects this unique engine is much larger than any engine previously built.

Cylinders, { H. P. (2) 20 in. x 32 in.
{ L. P. (2) 32 in. x 32 in.
Wheels, 56-in. diameter.
Wheelbase of coupled wheels, 10 ft.
Total wheelbase of engine, 30 ft. 8 in.
Valves—H P., piston type. L. P., Allen-Richardson type.
Steam pressure, 235 lbs. per square inch.
Boiler, internal diameter of first ring, 6 ft. 10 in.
Tubes (436)—2¼-in. diameter, 21 ft. long.

Heating surface—	Tubes	5366.3 sq. ft.
	Firebox	219.4 sq. ft.
	Total	5585.7 sq. ft.

Grate area, 72.2 sq. ft.
Height of top of smokestack above rails, 15 ft.
Firebox—Length, 108 in.
Width, 96¼ in.
Depth in front, 72 in.
Weight of engine in working order, 149¼ tons (English).
Weight of tender, 64 tons.
Coal capacity of tender, 13 tons.
Water capacity of tender, 7000 gallons.

This engine is to be subjected, with others, to exhaustive trials by means of the locomotive testing plan installed by the Pennsylvania Railroad at the St. Louis exhibition, and the results will, no doubt, be exceedingly interesting, while there can be little question that when No. 2400 is set to regular work, she will acquit herself creditably and amply justify the radical departures from ordinary practice which are included in the design.

The writer is indebted to the builders, the American Locomotive Company, for the photograph of the engine, and for particulars and data concerning its construction and dimensions.

VARIABLE-SPEED APPLIANCES

By E. K. Hood

If one makes even a cursory survey of the appliances used in the various mechanical industries for obtaining the proper machine speeds, he will be surprised, first, by the very crude methods employed prior to the last decade, and second, at the remarkable advances made since that time.

Considering first the requirements in the machine shop, we find a great variation in materials worked, a great variation in the tools used, and a still greater variation in the workmen. The cutting speed of a tool and the limit at which the material can be cut must primarily be determined by the workman, or his foreman. His judgment should be based upon experience and experimenting. The lathe builder provided for this in his original designs by the step-cone, and this device has been used for many years without change, except in proportions, in spite of the fact that it gave only a crude approximation to the speeds desired.

Take, for instance, a piece of work for which one step gives too slow a speed for economy and the next step too high a one for the limits of the tool. Inevitably the output will be below the maximum of the machine tool and of the man. This is true also of a job of facing or cutting-off. If the speed be correct at the moment of starting, it will be incorrect the next moment.

The results of a series of experiments, conducted last year by Mr. H. M. Norris, of Cincinnati, Ohio, led to the re-designing of the cone pulley on a lathe with a view to adapting it to the increased cutting speeds now demanded by the use of special steels for cutting tools. This lathe is especially adapted for turning shafts ranging from 1 inch to 4 inches in diameter. The cone, with back gears included, is designed to give speed ranges on the spindle,

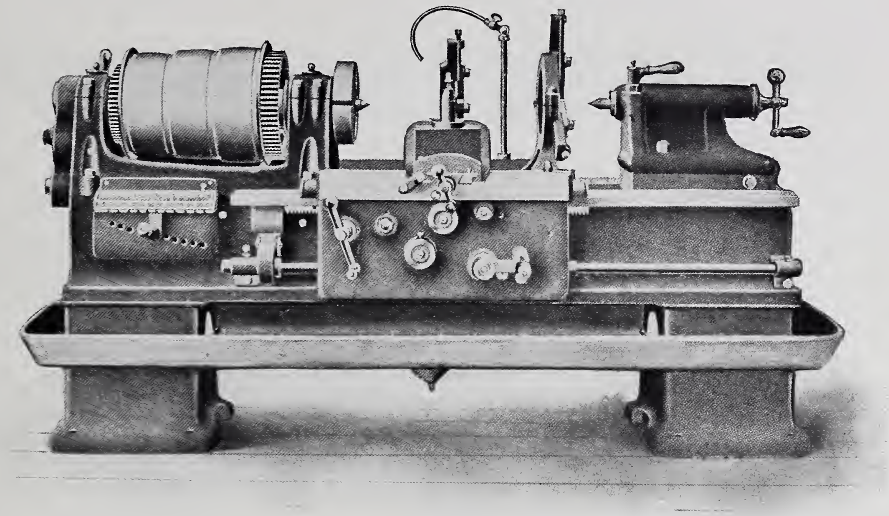


FIG. 1.—A HIGH-SPEED LATHE, MADE BY THE AMERICAN TOOL WORKS CO., CINCINNATI, OHIO, U. S. A. NOTE THE WIDE BELT CONTACTS AND THE LARGE CONE DIAMETERS

which will keep the work at practically the same cutting speed for all diameters between the different limits. It will thus be seen that a differently proportioned cone will be required for different classes of work and different sizes of machines. The ordinary lathe cone gives a greater range of speed, but on this class of work Mr. Norris contends it is not needed, as, in these days of manufacturing, machine tools are put on practically one class of work and are kept at that work for long periods of time.

One admirable feature presented in this lathe is in the wide belt contact and large cone diameters it affords. The cones, however, require no more space on the spindles than formerly. The American Tool Works Company, of Cincinnati, Ohio, U. S. A., have placed on the market a lathe embodying the suggestions made by Mr. Norris. This is shown in Fig. 1. The new design is infinitely better than the standard step-cone for the classes of work mentioned; but it still lacks the in-between speeds so essential on account of the varying degrees of hardness and toughness found in the same or in different materials.

An endeavour to fill in these gaps has led the builder to provide a multitude of feeds which the workman must use in connection with the speeds. Anyone who has stood in front of a lathe and intelligently handled the tool knows that he could work everything to its limit of speed if he could only " feel " for the limit. This cannot be accomplished with a step in speeds and a step in feeds. The builders of machine tools are realising this more and more each year.

A notable instance of the lack of variable speed in the machine shop is applied by the planing machine. The roughing cut, the smoothing cut, steel, cast iron, and brass are all worked at one speed. This speed must neces-

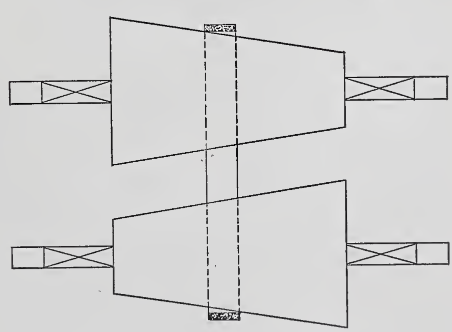


FIG. 2.—THE DOUBLE-CONE VARIABLE-SPEED GEAR

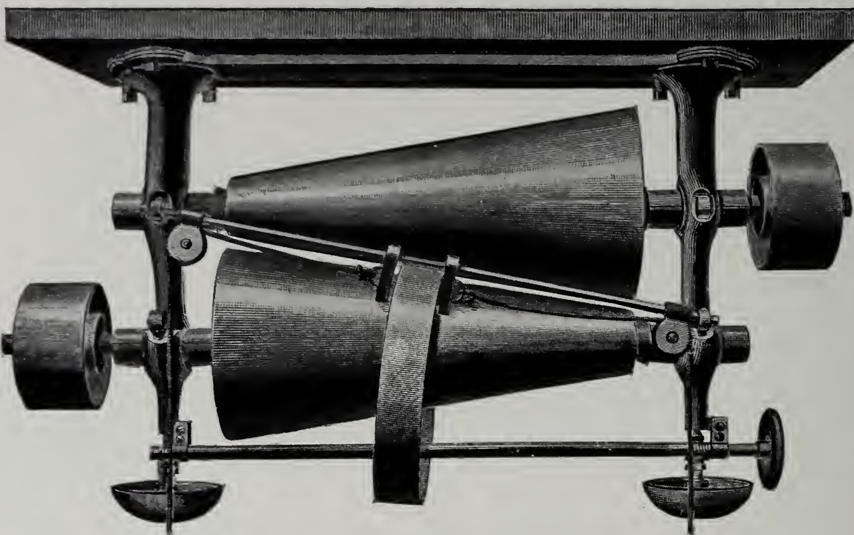


FIG. 3.—EVANS CONES, MADE BY GEORGE F. EVANS, BOSTON, MASS., U. S. A.

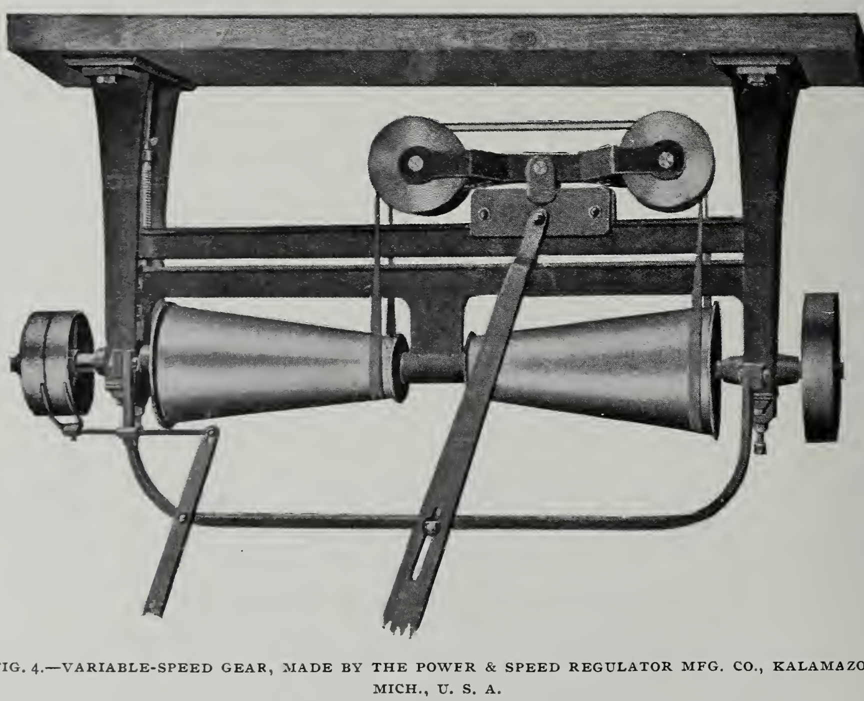


FIG. 4.—VARIABLE-SPEED GEAR, MADE BY THE POWER & SPEED REGULATOR MFG. CO., KALAMAZOO, MICH., U. S. A.

sarily be for the slowest working material, and when anything else is worked the maximum output is not produced.

But the field of variable speed is not limited to the machine shop. The paper mill is a place where large units of power must be varied in speed; printing establishments, too; canning factories; in fact, practically every line of industry requires variable speed. Accordingly, there has been opened a field of invention which has lain dormant for many years, and the variable-speed device to-day which will give an infinite variation between its limits finds a ready sale.

Looking back over this field, we find first the double cone arrangement, consisting of two true cones placed on parallel shafts, as shown in Fig. 2, provided with a belt passing around these cones. This belt is held by a guide which shifts it from one end to the other, and infinite variations of speed between the limits of the arrangement can thus be obtained. Despite the very apparent mechanical defect of the two edges of the belt travelling on different working diameters at the same time, this device found favour years ago, and is still used in many places where the range in speed is only slight. True, the belt wears out quickly, but the manifold advantages of this variation led the purchaser to overlook this drawback.

The next step along this line of cone-speed device is represented by the Evans cone. This device, shown in Fig. 3, consists of two true cones placed in practically the same relative positions as those in Fig. 2, except that they are held close together and a short, endless belt is "pinched" between the adjacent faces of the cones. One cone is adjustable relative to the other so that this "pinch" can be governed. The power is transmitted from one cone to the other by means of this belt rolling between them. A guide and shifter handles the belt, and very good results can be obtained with the device where light loads are to be transmitted. The belt has practically no slippage between the cones, and is limited in transmission capacity only by its slight surface contact. An attempt to transmit a large amount of power brings an undue pressure on the belt and bearings which, of course, affects the efficiency of the mechanism.

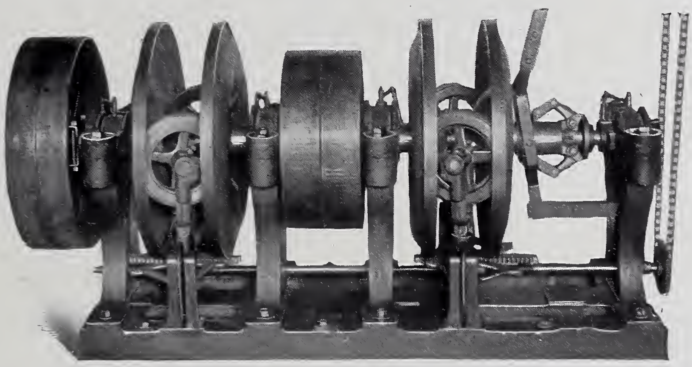


FIG. 5.—VARIABLE-SPEED DEVICE MADE BY THE CONSOLIDATED MACHINE SPECIALTY COMPANY, BOSTON, MASS.

A recently invented device is shown in Fig. 4. This consists of two cones mounted on a shaft in the same plane, having their small ends facing each other. A very narrow belt passes around them and over a shifting traveller guide above the cones. By shifting this traveller from one position to another, the driving diameters of the cones are changed and the variation in speed is accomplished. One apparent advantage in this is the very narrow belt which reduces its slipping action on the cones. A disadvantage would seem to be the absence of means for guiding the belt close to the cones. The belt would, undoubt-

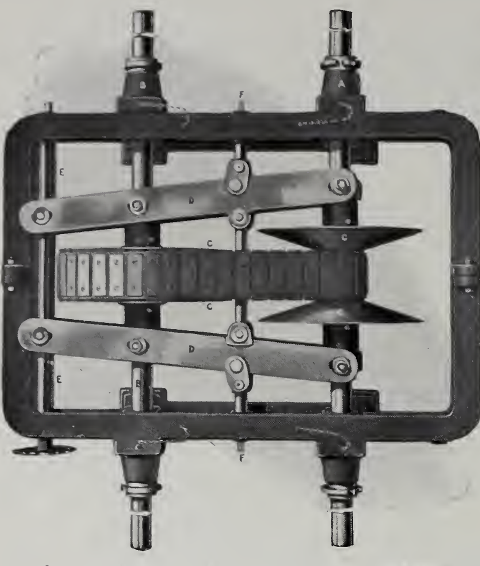


FIG. 6.—THE REEVES VARIABLE-SPEED TRANSMISSION DEVICE. MADE BY THE REEVES PULLEY CO., COLUMBUS, INDIANA, U. S. A. DRIVING AT MINIMUM SPEED

edly, tend to climb on the cones, and to successfully attempt to hold a belt out of its natural line it is necessary to guide it at the point where it tries to take the unnatural path.

A unique form of variable-speed transmission device, made by the Moore & White Co., Philadelphia, consists of two parallel shafts carrying cones provided with special slatted belts. The slats have their faces tapered to fit the taper of the cones. The outer surfaces of these belts are, therefore, straight, with elements parallel to the axes of the cones and form the driving surfaces for a third belt which passes around the cones, as represented in the cut. Guides prevent the special belts from climbing, and also serve to shift them to the desired positions and hold them there. The special belts are under no tension, and are not materially affected by any slipping action of the driving belt.

Of the disc transmission, so well known, and met with oftentimes in old machine tools for driving feeds, various forms have been placed upon the market from time to time, all having the common feature of transmitting power through a line of contact produced by friction, thus limiting their capacity to small units of power.

The next step along this line was the dished type, shown in Fig. 5. This consists of two pairs of dished discs with rollers mounted between them on pivots properly located so that they may be turned and make contact with different driving diameters of the discs. In the device shown in Fig. 8 several lines of contact are provided by using three rollers or travellers which make contact with revolving discs. The first device of this kind had two rollers, while later types have been provided with three or more. The advantage claimed for this device is its compactness. The discs are held in contact with the transmitter rollers by a spring. Variation in speed is effected by shifting the rollers as already mentioned.

The expanding pulley type of variable-speed transmission, although invented many years ago, has not become commercially successful, due in all probability to mechanical defects, such as complication of parts and lack of continuous belt surface. These defects may

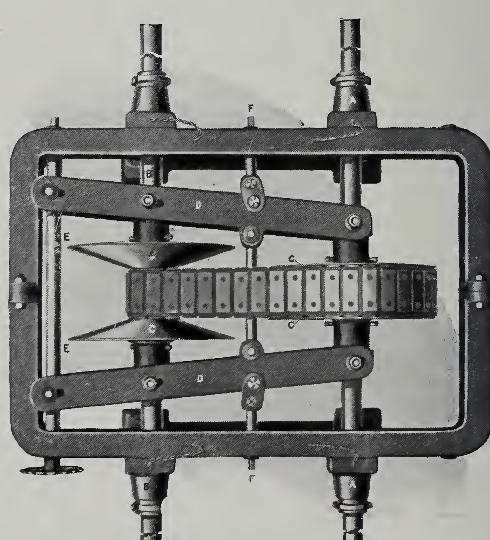


FIG. 7.—THE REEVES GEAR DRIVING AT MAXIMUM SPEED

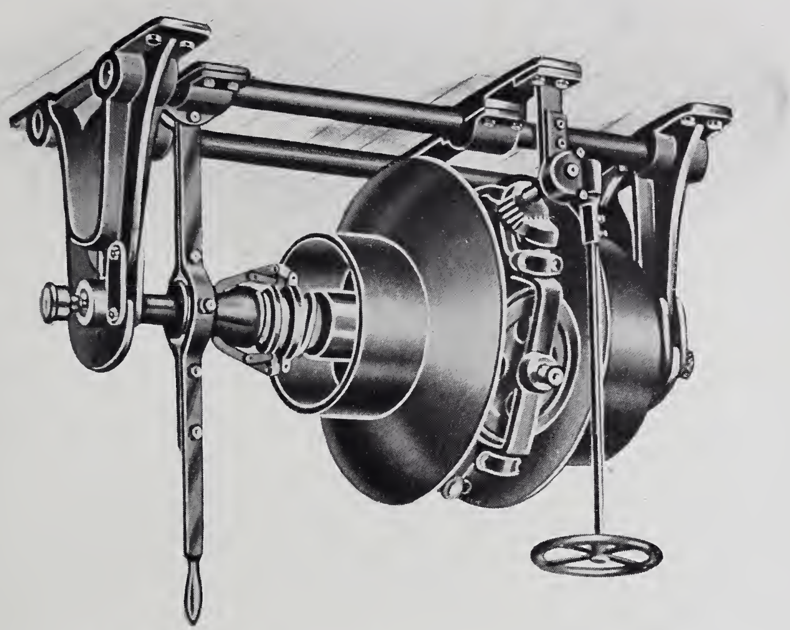


FIG. 8.—GEAR MADE BY THE SPEED-CHANGING PULLEY CO., INDIANAPOLIS, IND., U. S. A.

be overcome and a device of this character may be developed to meet commercial requirements which will present many advantages, among others its ability to transmit large loads.

Figs. 6 and 7 show another device, consisting of two parallel shafts, each carrying a pair of conical discs with their cone surfaces facing each other. A *V*-shaped groove is thus formed between the discs, and a specially constructed belt, with its edges as driving surfaces, is stretched between the pairs of discs, which, when operated simultaneously in opposite directions, permits the belt to assume different driving diameters and thus produce an infinite variation in speed, within the limits of the machine. The device is provided with means for giving the belt any desired initial tension, and the shifting mechanism is so constructed that this tension is maintained at all speeds.

The only defect in this system of transmission appears to be the specially constructed belt. The life of this belt is an unknown quantity. The writer knows of such belts which have been running continuously for six years. These belts are loaded moderately, and appear to be in good condition.

There seems to be no limit to the size and capacity of these machines, as the belt contact can be increased to meet any load requirements by increasing the diameter of the discs.

INDUSTRIAL LOCOMOTIVES

FOR MINING, FACTORY AND ALLIED USES

PART III—ELECTRIC LOCOMOTIVES

Parts I. and II., dealing, respectively, with "Steam Locomotives" and "Compressed Air and Internal Combustion Locomotives," appeared in the July and August issues

By J. F. Gairns

THE design of electric locomotives for mining and general industrial use has received considerable attention, particularly on the continent, during the last decade. As soon as the experimental days of electric traction were passed and the electric locomotive could be said to be a practical and safe machine, the immense advantages it possessed as compared with steam and compressed air locomotives were quickly realised. These advantages are the compactness of build, the obtaining of great power by means of a relatively small engine, the absence of a furnace and of a boiler or reservoir, the simple arrangements necessary for the supply of current, and its peculiar adaptability for odd-and-end work. It is, therefore, not surprising that electric locomotives specially designed for work such as we are now considering are in use in large numbers with very satisfactory results, and in several instances are displacing

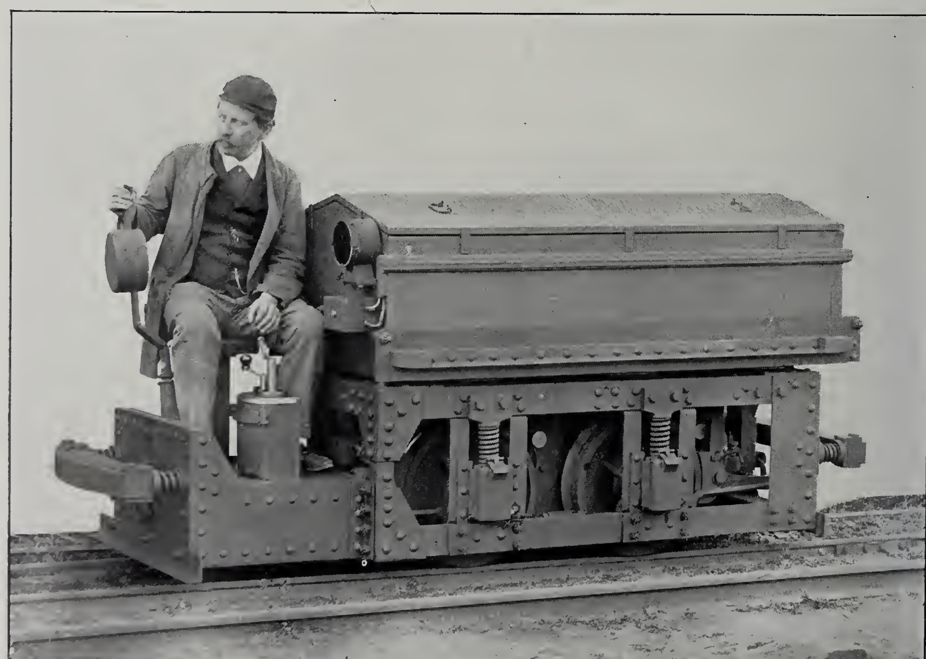


FIG. 44.—A STORAGE BATTERY LOCOMOTIVE BUILT BY MESSRS. SIEMENS & HALSKE, BERLIN

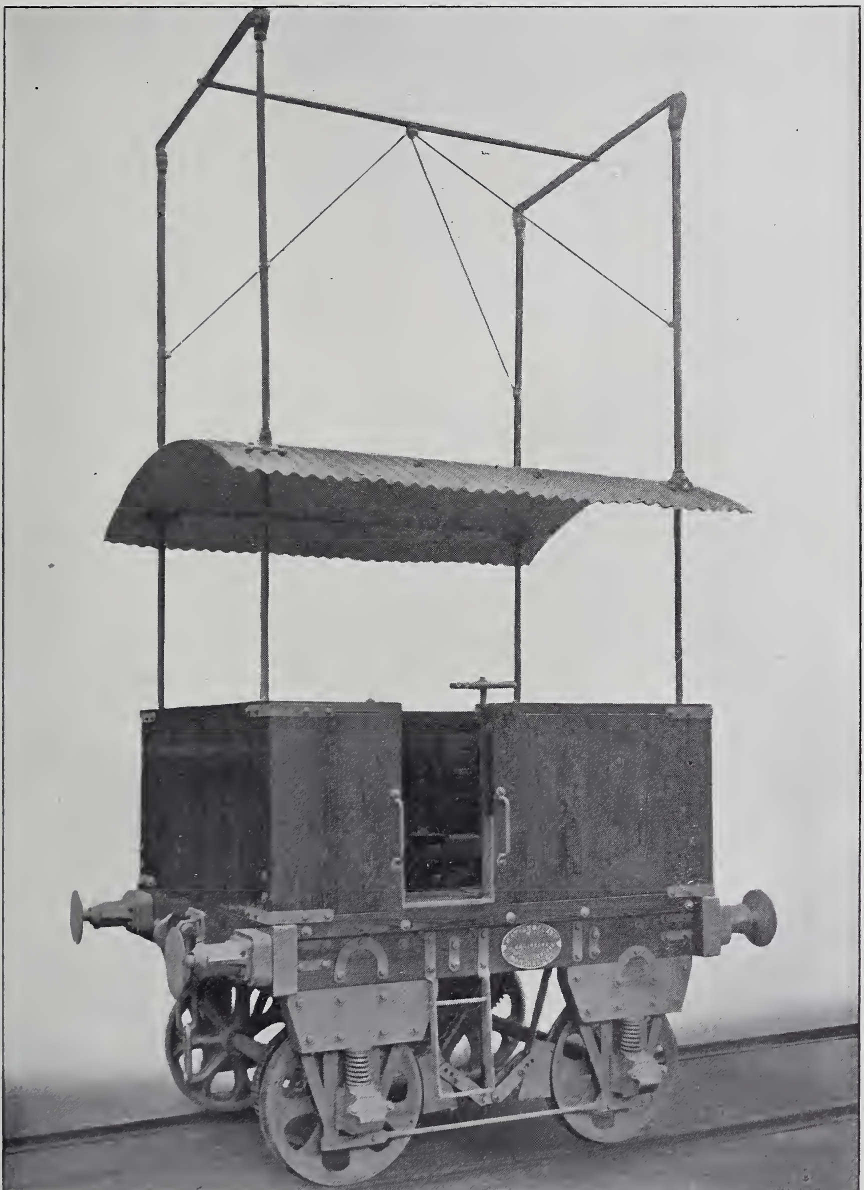


FIG. 45.—A SHUNTING LOCOMOTIVE BUILT BY MESSRS. MATHER & PLATT, LTD., MANCHESTER, ENGLAND

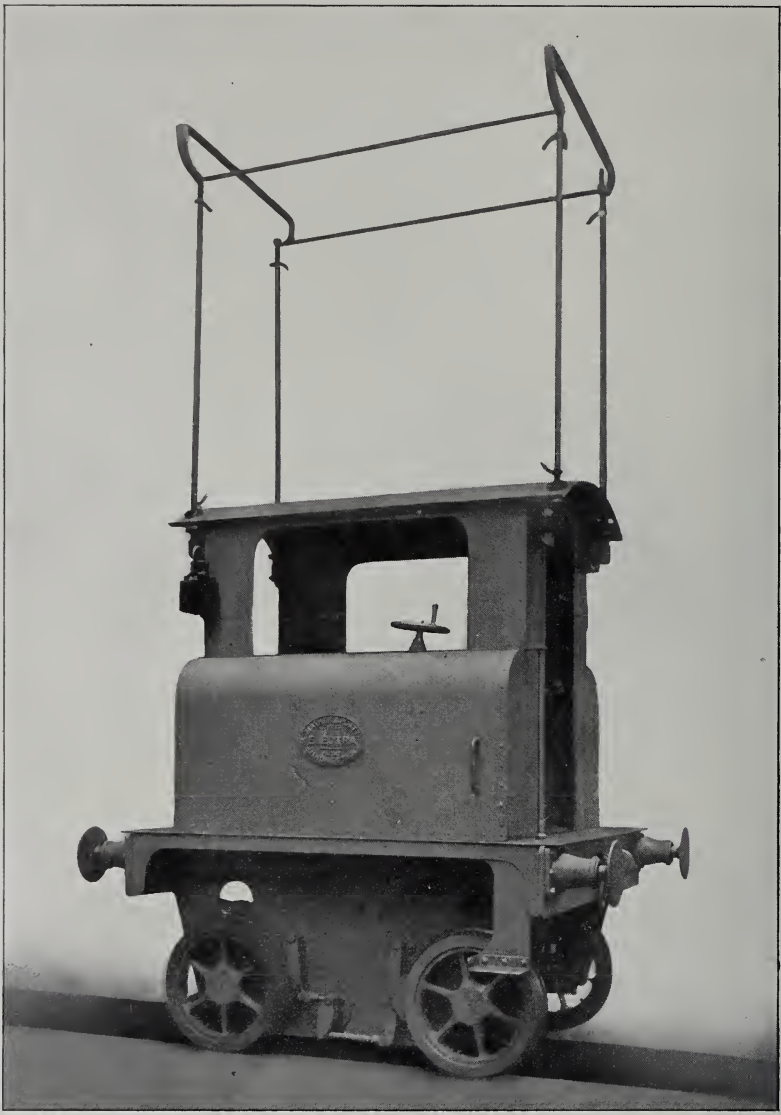


FIG. 46.—AN ELECTRIC SHUNTING LOCOMOTIVE BUILT BY MESSRS. MATHER & PLATT, LTD., MANCHESTER, ENGLAND

the steam and compressed air locomotives previously in use.

It is true that there are disadvantages as well, and the use of electric locomotives in " fiery " collieries would be attended with danger, owing to risk of explosion through sparking or short-circuiting, though on this point authorities are widely divided and the case may be considered doubtful; but in other mines, in shunting yards, and about works and factories, the present position of the electric locomotive is a very strong one, and there are many hundreds of them in use at the present time doing good work and giving good commercial results as well as practical service. It is not possible, in this arti-

cle, to exhaust the subject, and besides the actual locomotives to be described in this section the writer possesses particulars of dozens of others; but an attempt will be made to indicate what is being done as thoroughly as space will allow.

The first installation of electric locomotives for use in mines—and this practically antedates any attempt to apply electric traction for other than tramway work—is due to the great electrical firm of Siemens & Halske, and was put down in the Oppel shaft of the Zaucheroda Collieries in Saxony, in 1883. The locomotive was mounted on two axles driven by gearing from a motor: it was 8 feet long, 2 feet 7½ inches wide, and 5 feet high, and it worked on 22-inch gauge lines for a working length of about three furlongs. In practice it could deal with trains of fifteen tubs each, loaded with 9 cwt. of coal. Usually the locomotive pushed, not pulled, the train. In design, the locomotive was double-ended and the driver changed from one end to the other according to the direction of travel. After a short while, a second locomotive was provided for working another shaft, and then the electric traction equipment of the mine comprised the two locomotives

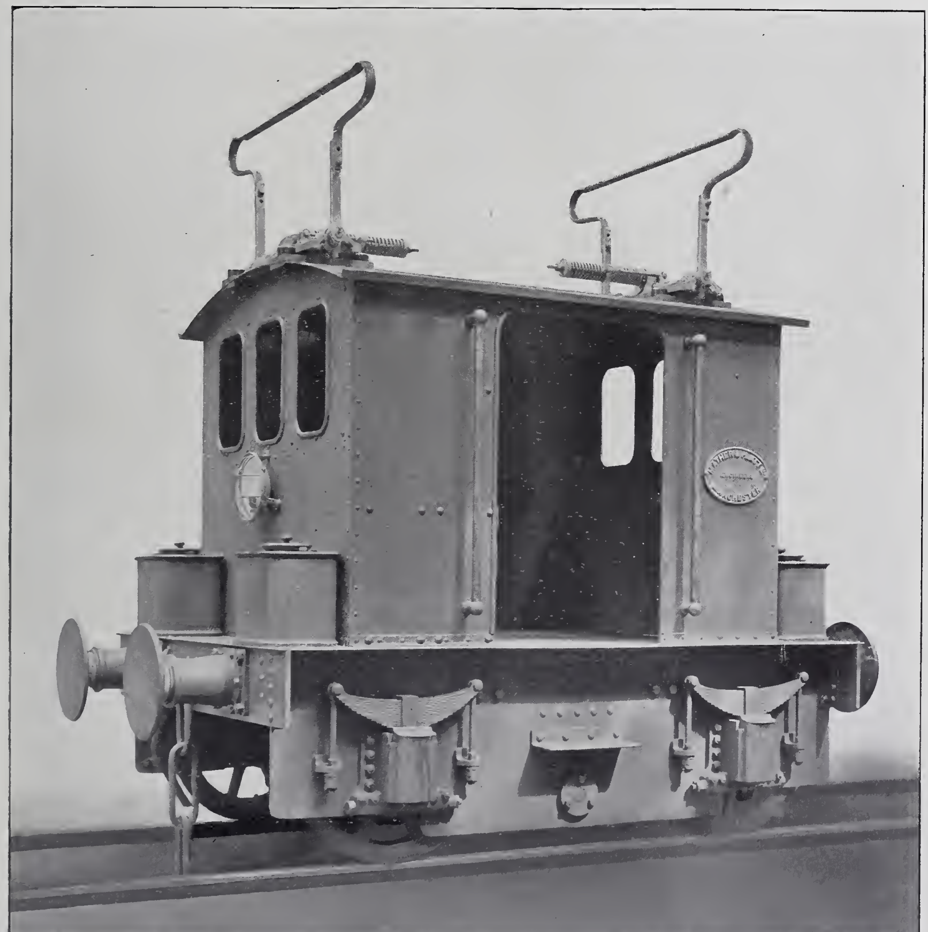


FIG. 47—A MINE LOCOMOTIVE BUILT BY MESSRS. MATHER & PLATT, LTD.

FIG. 48.—ELECTRIC LOCOMOTIVES IN A GERMAN "DRIFT" MINE

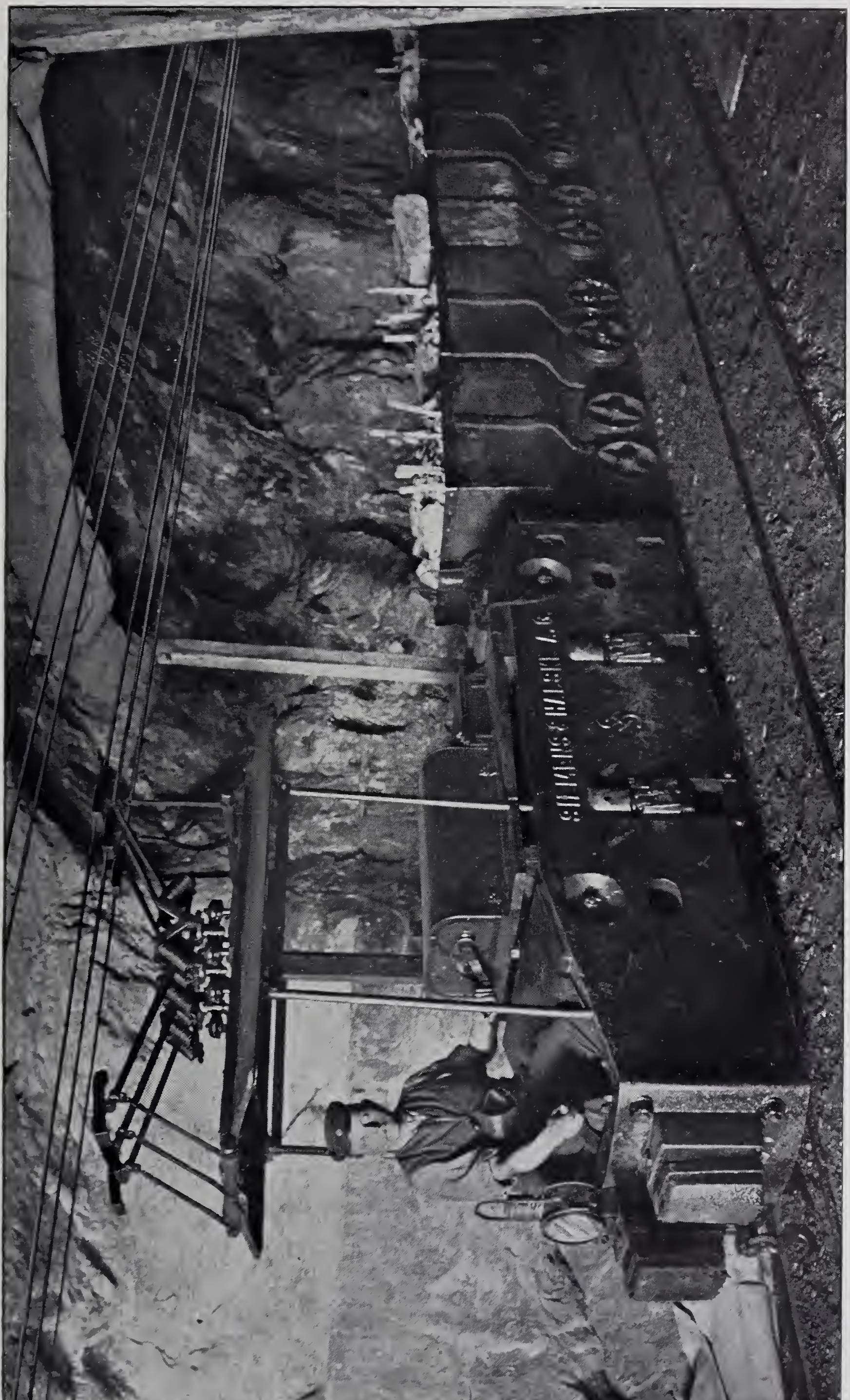


FIG. 49.—A THREE-PHASE MINE LOCOMOTIVE BUILT BY MESSRS. SIEMENS & HALSKE, BERLIN

and an electrically-driven haulage chain in a heavily graded part of the mine.

In 1883, electric locomotives were also adopted in the Consolidated Paulus and Hohenzollern Colliery at Beuthen, and in 1884, at New Stassfurt, both places being in Upper Silesia. Shortly after, the Aschenborn shaft of the Gottessegen mine in the same district was similarly equipped. At about the same time, the Allegemeine Elektricitäts Gesellschaft entered the field a competitor for the work, and equipped the Consolidated Konig and Laura mines in upper Silesia.

Very few particulars of these locomotives are available now; but from the information in the writer's possession, in the Siemens & Halske locomotives just mentioned the motor was mounted longitudinally on the frame and drove by bevel gearing, through an inclined shaft, a spindle, which geared on either side with one of the running axles. Two overhead conductors of rail construction were used, contact roller sleds, on wheels, or in some instances, contact sliding sleds, running on the conductors. The Allgemeine Elektricitäts Gesellschaft locomotives were somewhat similar, though they differed considerably in construction details.

Without going fully into history, these five cases of the installation of electric locomotives for mining work—none of the mines in question are "fiery"—mark the initial attempts to apply electric traction for displacing animal power in collieries and the like, and although in one or two cases the electrical locomotive equipment did not last, they represent early work on the part of the pioneer firm of Siemens & Halske, and also of the Allgemeine Elektricitäts Gesellschaft, which has given data and provided experience for further locomotive designs, which, as electrical engineering has developed, have given us the efficient mining and industrial locomotive of to-day.

In Great Britain, the electric locomotive as an industrial machine has received little attention until recent years, and for mining work, locomotive power of any kind is hardly used at all, owing to the difference in the conditions there and on the Continent and in America; but an early experiment in electric loco-

FIG. 50.—A SIEMENS & HALSKE DOUBLE LOCOMOTIVE

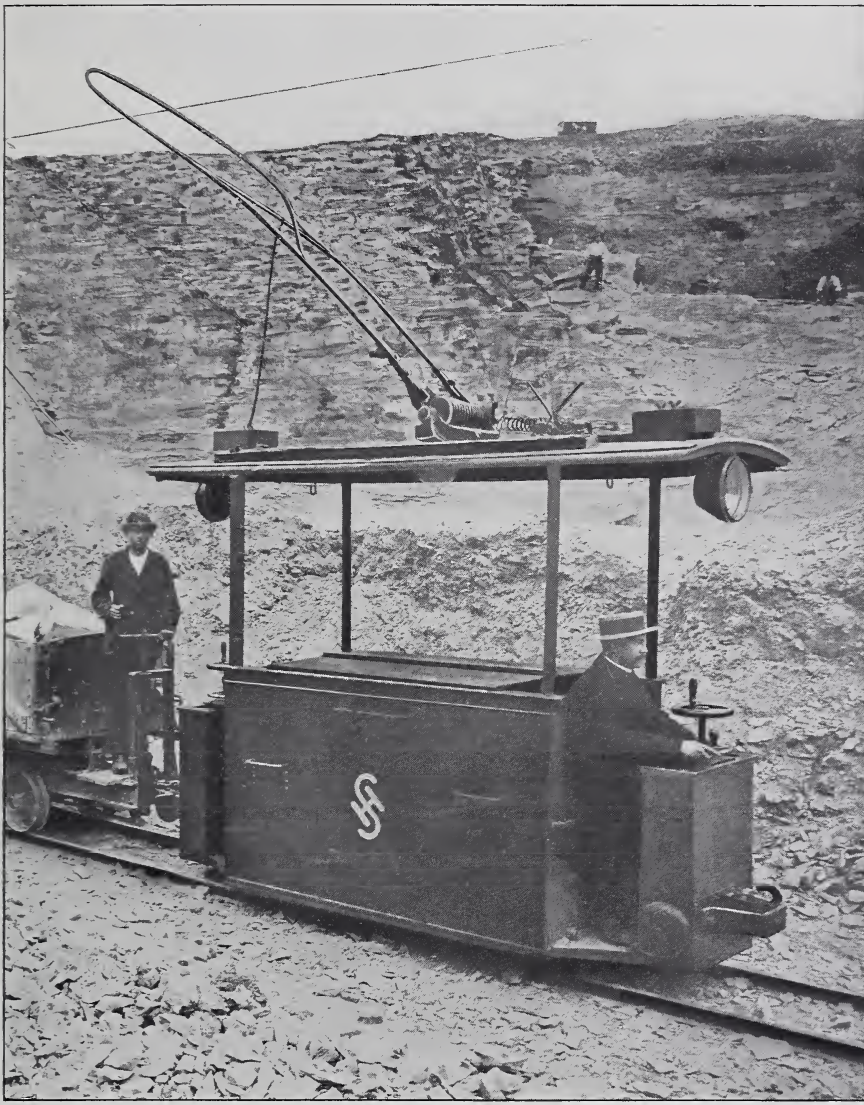


FIG. 51.—A SIEMENS & HALSKE LOCOMOTIVE AT WORK IN A CHALK PIT

motive traction at an English colliery is worthy of notice here.

In 1890, the General Electric Power and Traction Company installed an electric locomotive, working on a system designed by Messrs. Immisch & Walker, in the Wharncliffe Silkstone Colliery for working on an incline of about 1 to 9 and about 500 yards long. A fixed cable was fitted and a 10 horse-power electric motor on the locomotive hauled on the cable and so pulled tubs loaded to about 4 tons. Current was supplied by means of an overhead wire. The headway was 4 feet 3 inches only. This locomotive worked well for some time, and may be still in use. The locomotive and installation was fully described in Vol. CIV of the Proceedings of the Institution of Civil Engineers of Great

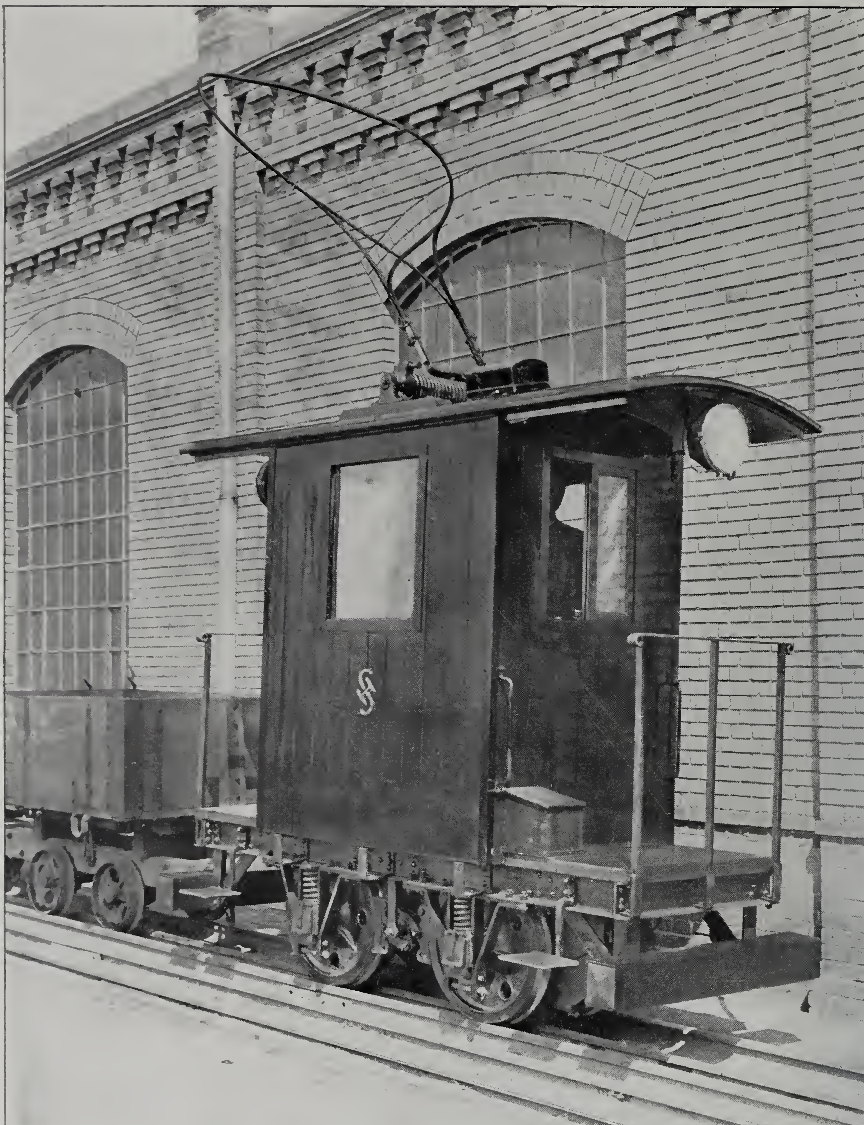


FIG. 53.—A SIEMENS & HALSKE FACTORY LOCOMOTIVE

Britain. In America, the first electric mining locomoitve was installed at the Erie Colliery in 1889.

It will now be well to consider a few actual examples of electric locomotives for mining and general factory and like service as built at the present time by the leading firms. Although Great Britain has done comparatively little work in this direction, there are a few firms who have produced electric locomotives for use about factories and in non-fiery mines, and by the courtesy of Messrs. Mather & Platt, Ltd., of the Salford Iron Works, three of their productions are illustrated here, one of which has not previously been described in the public press.

Fig. 45 illustrates a small locomotive built about 10 years ago, and supplied

to the textile machinery works of Messrs. Tweedale & Smalley, of Castleton. It is designed to draw a loaded waggon, not exceeding twenty tons weight, at a speed of about two miles an hour. It is used for shunting waggons on a siding connecting the boiler house and delivery stores of the textile machinery works with the main line. The current is supplied by overhead wires and returns through the rails, which are bonded with copper strips and rivets.

The locomotive somewhat resembles an ordinary goods waggon. It is fitted with coil-spring buffers of the standard height and centres, axle boxes and guides, and a hand screw brake with wooden brake blocks bearing on the car wheels, which are 28 inches in diameter. The locomotive is roofed in with galvanised corrugated iron carried on wrought iron pillars. These continue through the roof and carry the collector bars, which rub upon the conductor wire.

The driving motor is of the Manchester type, and is mounted on a cast iron bed plate which slides on cast iron brackets bolted to the framing of the car. The motor is fitted with a vulcanised fibre pinion with steel end plates of 21 teeth, the pinion gearing with a cut cast iron wheel of 72 teeth on the gudgeon shaft, on which is keyed a chain pinion of seven teeth, driving a chain wheel of 22 teeth, fitted upon one axle of the locomotive. A sand box is provided, and the car is fitted with a controlling switch, resistance box for starting and regulating the speed, and a reversing switch. The weight of the locomotive is a little over 3 tons.

The system of collectors on the locomotive lends itself particularly well to the requirements of this line, as there are many points, curves, and crossings. The system consists of two wrought iron bars placed about 6 feet apart, one of which is always rubbing on the under surface of the overhead wire. Fig. 46 shows another locomotive built by this firm for use as a shunting engine at a large iron works in Sweden. The locomotive is designed to draw a load of seventy tons, exclusive of its own weight, at a maximum speed of 4½ miles per hour. Current is supplied at a pressure of 300 to 330 volts. The gauge is standard and the wheels are of

FIG. 52.—AN ITALIAN QUARRY ELECTRIC LOCOMOTIVE BUILT BY MESSRS. SIEMENS & HALSKE, OF BERLIN

FIG. 54.—A SIEMENS & HALSKE ELECTRIC LOCOMOTIVE ON CONSTRUCTION WORK IN CONNECTION WITH THE BUILDING OF THE BERLIN OVERHEAD RAILWAY. NOTE THE DOUBLE CONDUCTOR RAILS BETWEEN THE RUNNING RAILS

steel, 27 inches in diameter, and the wheel base being 4 feet 6 inches. The side frames of the locomotive are of steel, and are somewhat deep for the size of the car, owing to the height of the buffers above the rail. The general design of the cab is similar to those built by Messrs. Mather & Platt, for the City and South London Railway. The motor is of the double-armature type made under the patents of Drs. J. & E. Hopkinson. Owing to the slow speeds at which the axles have to run the armatures are connected to them by means of spur gearing in the ratio of 10 to 1. There are two main switches, one of which is for stopping and starting by inserting or cutting out resistances from the main circuit, or for cutting off the current altogether, and the other is for reversing and for entirely breaking the connection between the locomotive and the main conductor.

The locomotive is arranged with overhead collecting gear, which has had to be carried to a height of about 16 feet from the rail, owing to the necessity of clearing certain obstacles with the bare overhead conductor. As a protection against the weather the whole of the

working parts is boxed in, as well as all the connections to the collectors, etc., this being necessary on account of the heavy falls of snow experienced in winter.

Fig. 47 illustrates a locomotive recently built by Mather & Platt for mining service. This locomotive is of standard gauge, and is fitted with a through two automatic reversible bar collectors, instead of trolley poles. It is fitted with a powerful hand screw brake, spring buffers, spring drawhook, and link at each end, sanding gear, head and tail lights in duplicate and foot gong. In addition to the series-parallel controller, there is also fitted in

FIG. 55.—A SIEMENS & HALSKE LOCOMOTIVE WITH CHAIN HAULAGE AUXILIARY FOR VERY HEAVY GRADES

motor on each axle, and a series-parallel controller. It is designed to haul 13 tons on a grade of 1 in 33 at a speed of 10 miles per hour, when supplied with current from the overhead conductor at a pressure of 500 volts, the return being by the rails. Current is conveyed from the overhead wire to the motors the cab an automatic cut out, lightning arrester, kicking coil, and the controller resistances. The motors are entirely enclosed, and carried partly on the axle and partly by springs from the under frame; they drive the axle by means of single reduction machine-cut gear, running continuously in oil. The weight

of the locomotive in working order is about 5¾ tons.

The Electrical Construction Company, and Messrs. Ernest, Scott & Mountain, Ltd., of Newcastle-on-Tyne, have also built several electric locomotives, and the British branches of some of the American firms also supply locomotives of the American types. Messrs. Kerr, Stuart & Co., Ltd., also catalogue a very small style of electric locomotive, more particularly designed for use where headway is limited, and adapted especially for "gathering" work in mines. A few of these have been built, though as no photographs are available they cannot be illustrated.

FIG. 56.—A PLATFORM FACTORY LOCOMOTIVE BUILT BY MESSRS. SIEMENS & HALSKE, BERLIN

The last-named engines are built of varying sizes, the smallest design having a 1-horse-power motor, and are capable of dealing with a load of 2 tons on the level at 5 miles an hour, while a

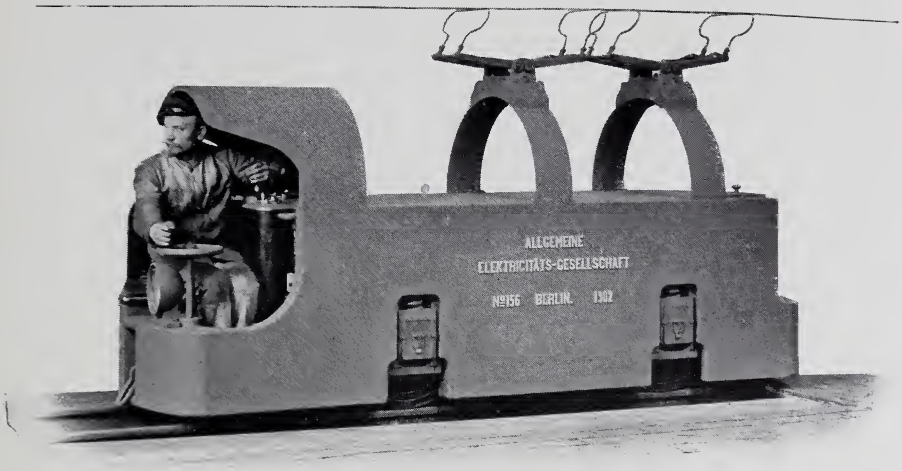


FIG. 58.—A MINE LOCOMOTIVE BUILT BY THE ALLGEMEINE ELEKTRICITÄTS-GESELLSCHAFT, BERLIN

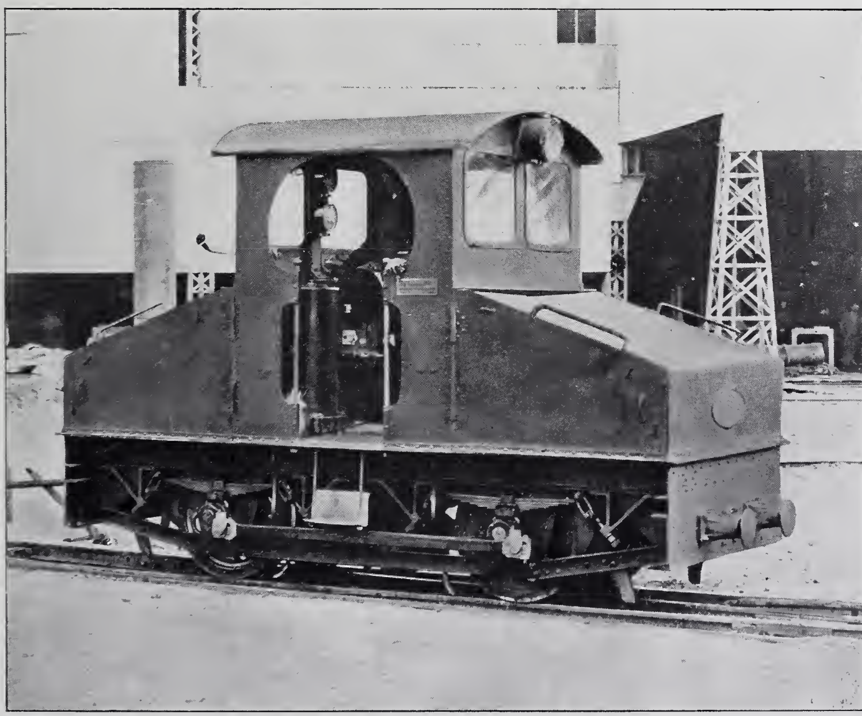
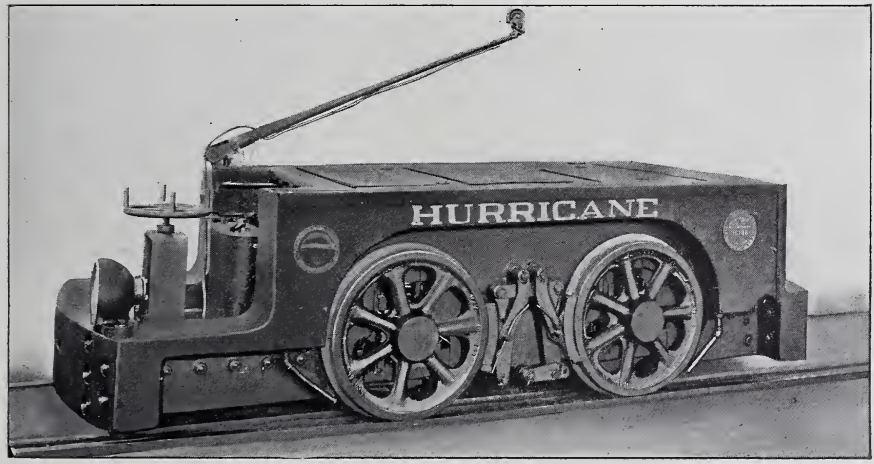


FIG. 57.—A STORAGE BATTERY LOCOMOTIVE MADE BY THE SAME COMPANY

FIG. 59.—A DOUBLE-END MINE LOCOMOTIVE MADE BY THE UNION ELEKTRICITÄTS-GESELLSCHAFT, BERLIN



FIGS. 60 AND 61.—BALDWIN-WESTINGHOUSE ELECTRIC MINE LOCOMOTIVES

larger type, with a 30-horse-power motor, is intended to haul 60 tons on the level or 15 tons on a grade of 1 to 20.

We will deal now with examples of electric locomotives as built by Messrs. Siemens & Halske. Fig. 44 illustrates an accumulator locomotive supplied to the Kohlenbergwerk Vereinigter Bonifacius zu Kray—Gelsenkirchen. Fig. 48 shows an interesting scene outside a German "drift" mine. On the one track is a mine passenger train ready to take miners to work, and on the other track is a loaded coal train just out of the mine. In this case there are double overhead conductors.

Fig. 49 is an interior flashlight photo showing a three-phase, alternating-current locomotive at work. In Fig. 50 a double electric locomotive is illustrated as used in several German mines. In this case the two locomotives are normally worked as one, the driver on one unit governing the whole; though if need be, either section can be operated independently and used as a single locomotive. These double locomotives are employed when adequate power cannot be obtained without unduly increasing

FIG. 62.—ANOTHER FORM OF BALDWIN-WESTINGHOUSE ELECTRIC LOCOMOTIVE

the size and weight of an ordinary locomotive or exceeding the allowable load per axle.

Fig. 51 illustrates a neat design of locomotive, with overhead conductors, at work in a chalk pit. In this case the height and width of the locomotive are not restricted, so that, in outward appearance, the locomotive differs from the mine locomotives previously described.

Fig. 52 shows another design as used at an Italian quarry. In this case double collectors are fitted so as to ensure constant contact with the overhead conductor, a practice usual for tramway and railway work, though rather rare for industrial service.

Fig. 53 illustrates another design as used about factories and the like; and Fig. 54 shows an interesting scene upon the Berlin Overhead Railway, the locomotive being used for hauling construction trains. In this instance, double conductor rails, which can be clearly seen between the running rails, are provided for the supply and the return of the current. The rough-and-ready arrangement of the narrow-gauge rails is worthy of notice as showing "how things are done."

Fig. 55 illustrates an interesting design of electric locomotive adapted for working over stiff gradients. Between the rails is fitted a chain, along which the locomotive hauls itself by means of a motor-driven drum, around which the chain is passed. The rail wheels are also driven by the motor. This locomotive, with three others, was supplied to the Roeros Copper mines in Norway in 1895. The grade is 30 per cent.

Fig. 56 illustrates a locomotive which also serves the purpose of a platform waggon—a form of locomotive for use about works in conveying goods from one shop to another and for like work.

In addition to the illustrated examples of locomotives, built by Messrs. Siemens & Halske, there are many variations, and they range from small engines for running "fair" and "show" railways—in such machines the motor casing forms the seat for the driver—to large

eight-wheeled locomotives for heavy work. Some have only one motor, others have two. Various systems of control are adopted, and there is great diversity in the construction and arrangement of current collectors, though the plain trolley pole, as used so extensively in Great Britain and America, is rather uncommon. Most of the systems of electrical distribution which are practically successful are in use, from the ordinary low-voltage, continuous-current to the high-tension, three-phase, alternating-current systems.

The A. E. G.—as the Allgemeine Elektricitäts Gesellschaft, of Berlin, is generally termed—have also done good work in connection with electric locomotives for the industrial service, and a few examples of their work will now be given.

Fig. 57 illustrates a storage battery locomotive, as supplied to a French steel works, hauling a train of foundry ladles. In this case, the motor drives one axle and coupling rods are employed.

The locomotive shown in Fig. 58 is for mining service, and is a good example of stock and ordinary design, though the arrangement of current collectors is rather unusual. Fig. 59 shows a large double-ended locomotive, built by the Union Elektricitäts Gesellschaft, now amalgamated with the A. E. G.

There are several other Continental firms who do a good business in electric locomotives for mining and like work, but enough has been said to indicate the principal characteristics of the designs in use. Suffice it, then, to mention that Messrs. Ganz & Co., of Buda Pesth, have equipped several mines with electric locomotives working on the high-voltage, alternating system with which their name is now so prominently associated.

In American practice there is more uniformity among the various locomotive types as now built than in the case of the German designs.

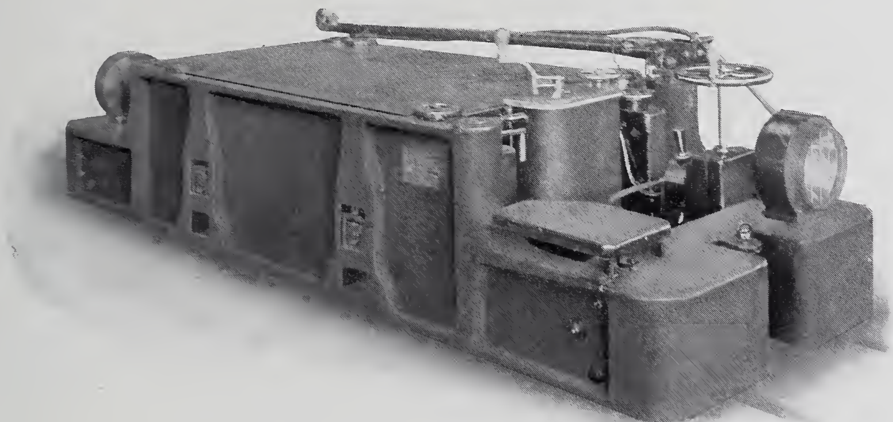


FIG 63.—A DOUBLE-END MINE LOCOMOTIVE BUILT BY THE GENERAL ELECTRIC COMPANY, SCHENECTADY, NEW YORK

Figs. 60 and 61 illustrate two examples of overhead trolley locomotives built jointly by the Baldwin Locomotive Works and the Westinghouse Electric and Manufacturing Company,—one for the Berwind-White Coal Mining Company and the other for the St. Louis and Big Muddy Coal Company, both of which are of substantially equal dimensions and power, though they differ considerably in details of design. In the one case the gauge is only 3 feet and in the other case it is 3 feet 8 inches,

FIG. 64.—A STORAGE BATTERY SHUNTING LOCOMOTIVE BUILT BY THE GENERAL ELECTRIC COMPANY, SCHENECTADY, NEW YORK

but both are designed to give a working capacity equal to 100 horse-power, at a speed of 8 miles an hour on the level. One 50-horse-power, single-reduction motor, suitable for a pressure of 500 volts, is geared to each axle. The drawbar pull for both engines is estimated at 4300 pounds on the level. Rheostatic controllers are fitted. The differences in details will be apparent on inspection of the photographs.

Of a different class, built by the same firm, and intended for surface work, is the locomotive illustrated in Fig. 62, belonging to the Golden Sceptre Gold Mining Company. In this case, larger dimensions are available, and so the engine is of a more ordinary type, and a proper casing is provided. The engine is guaranteed to exert 100 horse-power continuously for three hours at a speed of 6 miles per hour, and to haul a train of mine cars, weighing, in all, 35 tons, up a maximum grade of 1 to 20.

Two 50-horse-power double-reduction, consequent-pole motors are employed, one geared to each axle, the wheels being coupled.

Fig. 63 shows a double-ended mine locomotive built by the General Electric Company, of Schenectady, New York, and Fig. 64 represents a storage battery locomotive by the same builders, for yard switching and general service

about factories. Fig. 66 shows an interesting type of electric locomotives made by the Jeffrey Manufacturing Company, of Columbus, Ohio, U. S. A.

The locomotives described may be said to represent American practice fairly thoroughly, but this article would not be complete without reference to some special designs for which the Goodman Manufacturing Company, of Chicago, is responsible. This company exploits the Morgan third-rail system, which has been introduced with good results in mines having steep grades. This system simplifies the arrangements for supplying current to the locomotives.

Figs. 67 and 68 illustrate some of the construction details.

There are two standard types of locomotives used at the present time in operating this system:—First, that with a single motor, of 75 horse-power; weight, complete, 6000 pounds; maximum height from top of rail, 3½ feet; length, 7 feet; minimum gauge, 18 inches; second, the two-motor type of 150 horse-power; weight, complete, 10,000 pounds; maximum height from top of rail, 4 feet; length, 10 feet; minimum gauge, 18 inches. The motors for either of these locomotives are wound for 250 or 500 volts, as required.

FIG. 65.—A PLANTATION LOCOMOTIVE BY ARTHUR KOPPEL, OF LONDON, BERLIN AND NEW YORK

The locomotive itself consists of a substantial steel frame, mounted on suitable track wheels. On this steel frame are mounted two steel sprockets or traction wheels,—see Fig. 68—which are driven by one or more electric motors (according to the class) con-

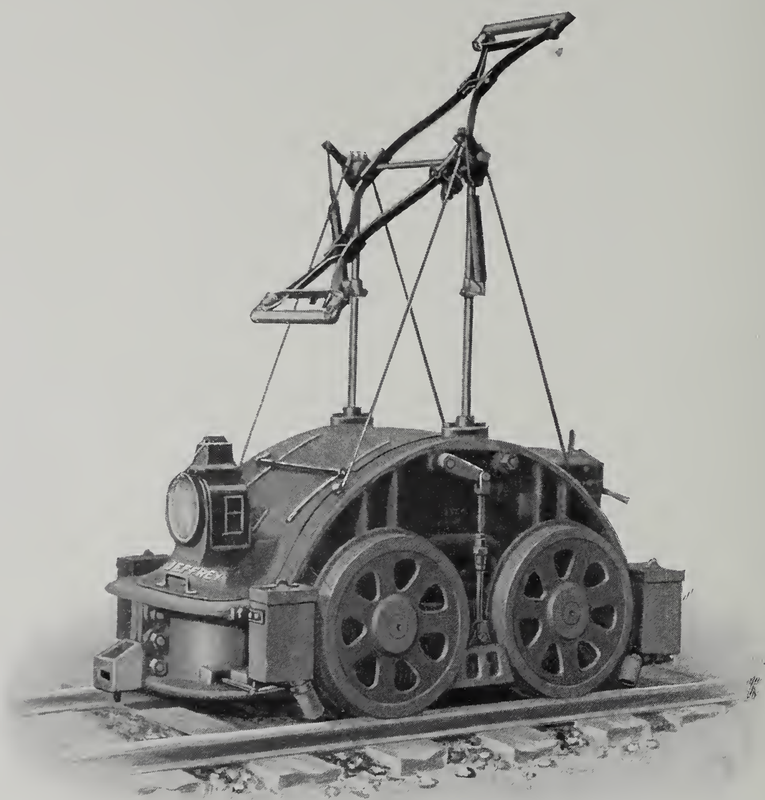


FIG. 66.—A GONDOLA TYPE ELECTRIC LOCOMOTIVE MADE BY THE JEFFREY MFG. CO., COLUMBUS, OHIO, U. S. A.

tained in the body of the locomotive, by means of suitable gearing. The sprocket wheels which engage the third rail serve the double purpose of driving the locomotive along the track and taking up the current from the rail to feed the electric motor;—hence the name "combined third and traction rail." The sprocket wheels are geared to always run in unison, all difficulty in crossing switches or other openings in the track thus being avoided.

The track rails are used as the return conductor. The third rail consists of heavy iron bars, perforated at regular intervals throughout their entire length, and made into a continuous rail by means of fish plates, much the same as regular track rails. This continuous rail is enclosed and depressed in a specially prepared wood casing, which serves the double purpose of insulating the rail and protecting men and animals from the current. It is laid five inches off the centre of the regular track, thus giving room for mules to work over the same rails and avoiding interruption to the working of the mine while the plant is being installed.

The sizes of third rail manufactured at the present time are designated as

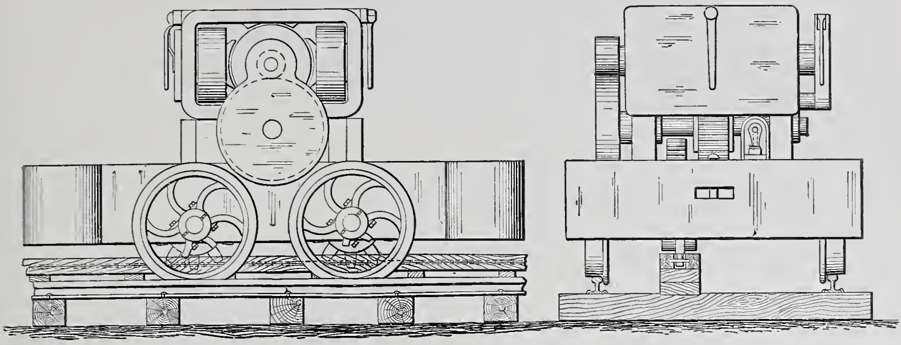


FIG. 67.—A THIRD-RAIL MINE LOCOMOTIVE MADE BY THE GOODMAN MFG. CO., CHICAGO

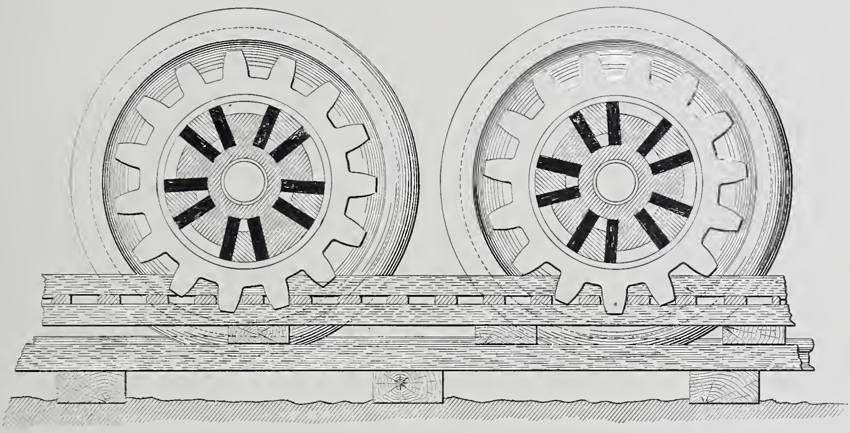


FIG. 68.—THIRD-RAIL AND PINION CONSTRUCTION

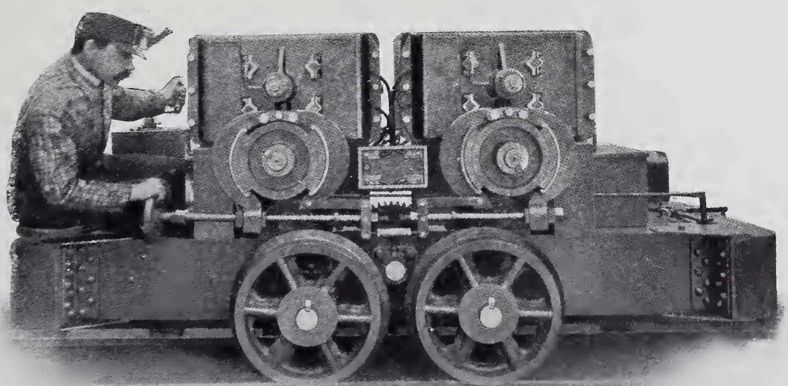


FIG. 69.—A DOUBLE-MOTOR THIRD-RAIL LOCOMOTIVE

standard, heavy, and special. The standard third rail is usually used with the one-motor locomotive, the heavy with the two-motor locomotive, and the special with either the standard or heavy for curves and switches. All sizes are furnished in straight 16-foot lengths.

A special "jim-crow" is furnished, which easily bends any of the above mentioned sizes of third rail to suit any curve met with in a mine. The various sizes of third rail are perfectly interchangeable,—that is, any of the third rail locomotives will work well over either standard, heavy or special third rail. Special arrangements have to be made at switches and crossings, but these cannot be considered here.

Fig. 69 illustrates a large double-motor third-rail locomotive.

The Goodman Company have also designed a locomotive for work with a headway of 32 inches only—probably the least ever attempted to work with mechanical haulage anywhere. In mines where the men can push the cars out of the rooms, mules can be dispensed with entirely by using these small locomotives, a great saving thus being effected. This company also build locomotives of more ordinary design, taking current from a trolley wire or from a conductor rail, but space will not permit of any of these being illustrated.

As a rule the continuous-current, low-voltage system is employed in the United States, though there are a few examples of the use of three-phase alternating currents.

It is very usual, too, to adapt electric coal-cutting machines of various kinds to self-propulsion by gearing the driving motor, when required, with one of the wheel axles of the carriage. Propelling motors are also fitted to "larrys" for feeding coke-ovens, and sometimes these motor-larrys will haul several trailers when required.

In conclusion, the writer would express his thanks to the numerous firms who have assisted in the supply of photographs and information, and would also acknowledge his indebtedness to many technical journals, British and foreign, for particulars of work done whereby this comparatively exhaustive survey of practice in various countries in reference to "mining, factory and industrial" locomotives has been rendered possible.

DROP-VALVE ENGINES

By Charles Hurst

IN its latest development the reciprocating steam engine of moderate speeds is provided with drop valves and trip gear, and is adapted for using highly superheated steam. In this article it is proposed to examine and illustrate a few recent examples of this type of engine, particularly with reference to their valve gear.

The outstanding feature of the valve gear of these engines is that both steam and exhaust valves, whether provided with trip gear or not, are not positively connected to their respective eccentrics or cams. This is a mechanical necessity with a valve that closes by falling upon a seat; and the remark applies equally to the valves of gas engines and of air compressors.

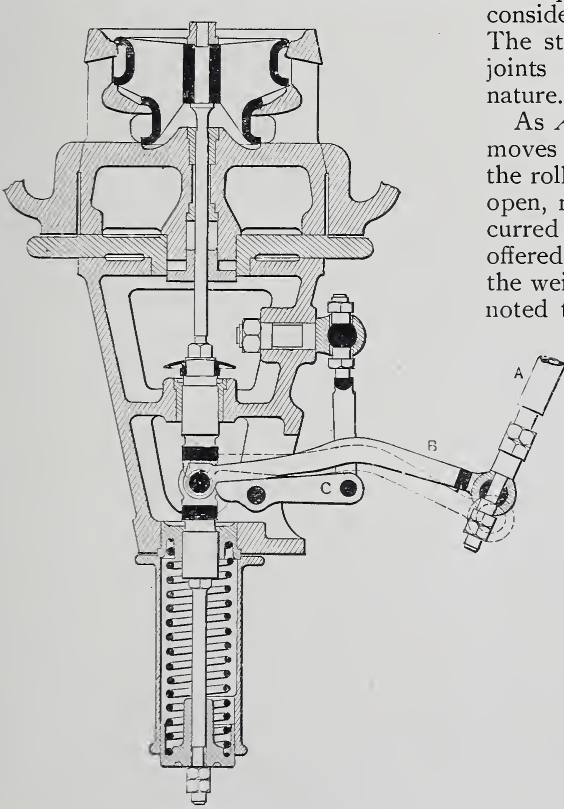
Before passing on to the consideration of particular designs, it will be interesting to notice a few points which should be observed in the design of drop valve gearing. A most important point is the elimination of the excessive stresses which occur at the instant the valves are lifted from their faces. Once the valves are open, they are practically in equilibrium, and the only resistance to be overcome is that of the closing springs

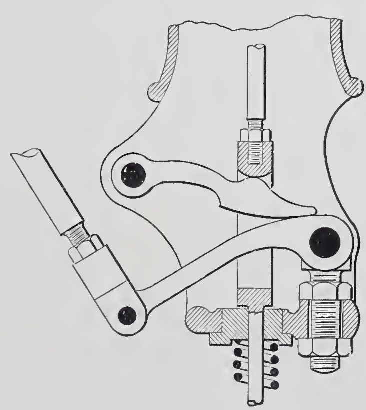
and the friction of the valve stem stuffing boxes. The period of maximum stress being momentary, it is possible to arrange the valve gearing so that at the instant of lifting of the valve, the eccentrics or cams act at such a leverage that the wear on them is inappreciable. This action is analogous to the lost arc or dwelling motion obtained by the wrist plates of Corliss engines. It may be accomplished by giving a suitable contour to cams, by the employment of rolling levers, or by properly designed tappets.

With respect to cam design, it is only necessary to provide an outline with a certain portion deviating slightly from a concentric line, and to place this cam in such a position on the valve shaft that the valve lever roller runs upon this portion when the time for valve opening occurs. This will enable the cam to have a momentary mechanical advantage over the valve which will relieve the cam and roller from undue stress and wear.

Figs. 1 and 2 illustrate arrangements of levers designed to give an easy opening to the exhaust valves and show the methods adopted by two leading firms of drop-valve engine builders. In the first example the rod *A*, which is driven by an eccentric on the lay or valve shaft, actuates the outer end of the rolling lever *B*, which rolls upon the adjustable pallett *C*. The rolling lever is shown in two positions, the one in full lines showing the action when the valve is on the point of being lifted from its seat, whilst the dotted lines indicate the extreme position in the opening direction, that is, when the valve has attained its maximum lift. Reverting to the just closed position, it will be seen that the point of contact between *B* and the adjustable pallett is near that end of the rolling lever which raises the valve, and consequently the rod *A* is acting at a considerable leverage on the valve. The stresses thrown upon the wearing joints are therefore of a very slight nature.

As *A* descends, the point of contact moves rapidly towards the outer end of the rolling lever, but as the valve is then open, no violent shock or stress is incurred thereby, the only resistance offered being that of the spring *C* and the weight of the valve. It will also be noted that by this arrangement a small





FIGS. 1 AND 2.—SOME TYPICAL DROP-VALVE GEARS

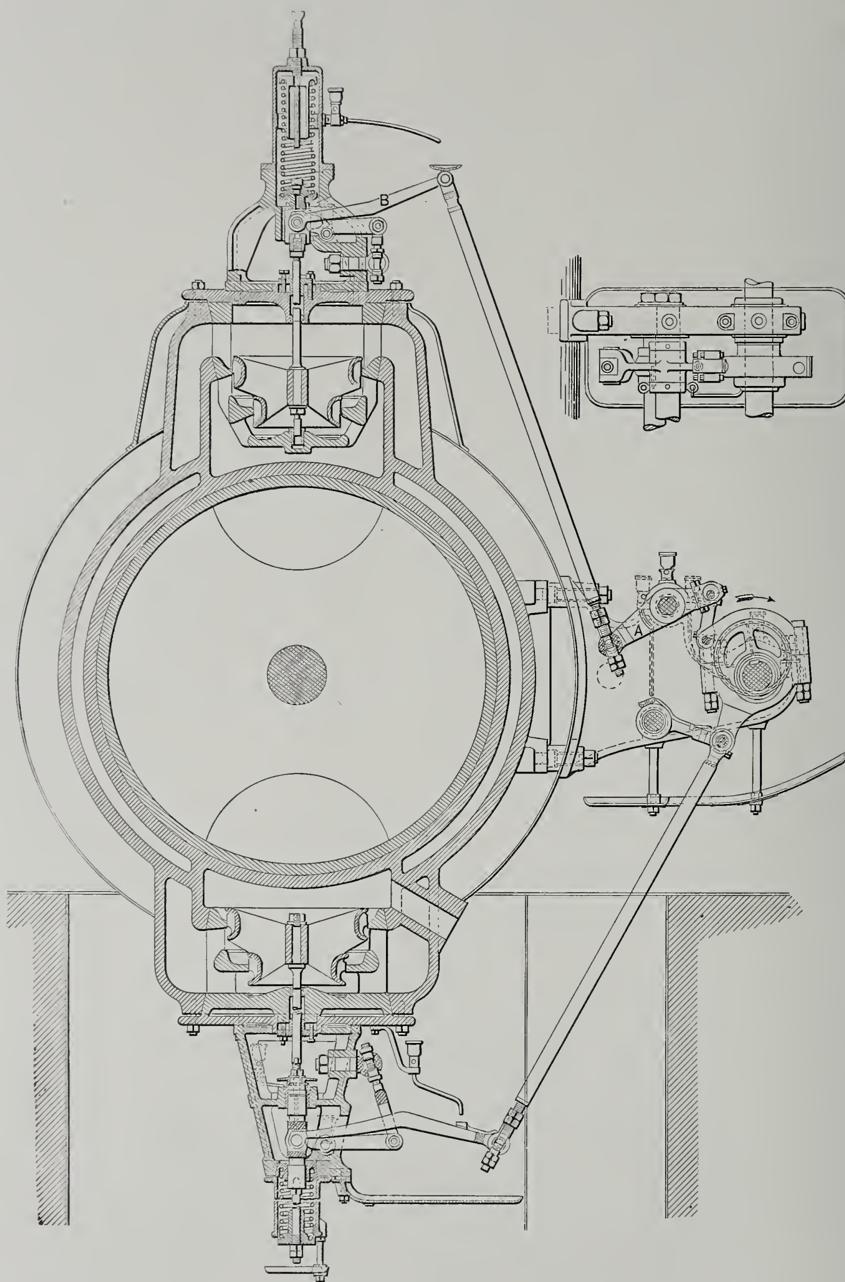


FIG. 2.—THE VALVE GEAR OF THE SULZER ENGINE, MADE BY MESSRS. SULZER BROTHERS, WINTERTHUR, SWITZERLAND

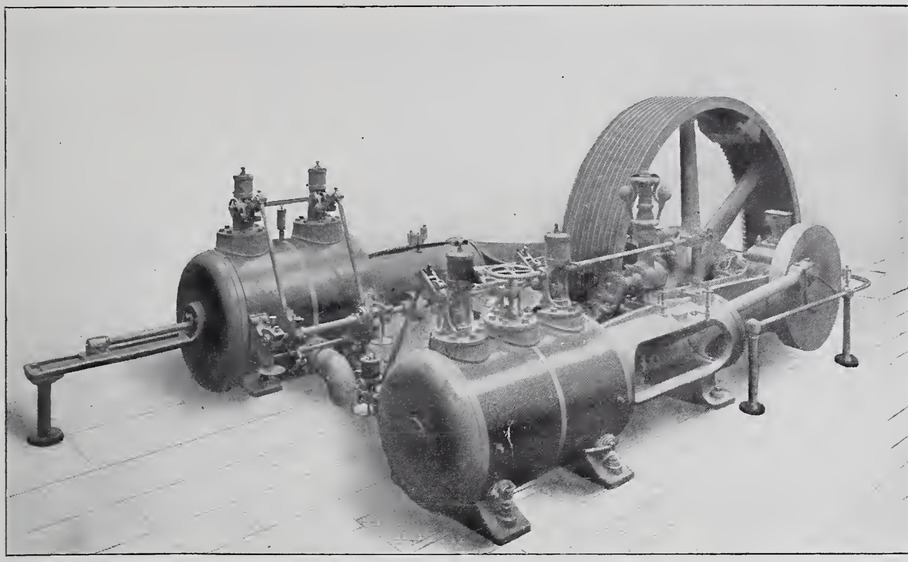


FIG. 4.—DROP-VALVE ENGINE MADE BY MESSRS. ROBEY & CO., LTD., LINCOLN, ENGLAND

travel of the lever *A* is sufficient to give adequate lift to the valve, the advantage of which is too well known to need discussion.

Although the primary object of the design here illustrated is to effect easy opening with a small movement of the valve mechanism, there is a considerable advantage in the fact that it makes the closing of the valve free from shock. This is an important matter with a valve of the type shown, because any approach to a hammering action would be destructive to the seats and valve faces. The return motion of the valve resulting from the rolling lever is the reverse of the opening action, being rapid for the first portion of the valve movement, but gradually decreasing in velocity as the valve approaches its seat, thus allowing it to assume the closed position entirely without jar or noise. Fig. 2 shows another arrangement to effect easy opening and closing. In this the action is similar to that already described.

The considerations which influence the design of the mechanism for actuating those steam valves which carry trip gear differ somewhat from those in the case of exhaust valves. The opening action is effected by the engagement of catches, and the problem is to bring the catches into contact at a low velocity so as to reduce noise and wear of the nibs. The next point is to slip the catches without " pluck " on the governor; and the final point is to cushion the rapidly descending valve so that its fall is not detrimental to the seating. The cushioning of a Corliss valve is not of supreme importance, since the valve slides over the port, and its closed position is not one of mathematical exactitude; but the efficient cushioning of a drop valve is essential to successful operation.

The workmanship of the valve gear must be first-class to obtain satisfactory operation for long periods. All the pin joints which are not adjustable should be carefully casehardened, and overhung pins should be avoided as far as possible, the forces being transmitted through the various levers without any cross-bending, which is liable to cause uneven wear and rattle in the mechanism, and when serious wear has taken place, efficient operation is impossible.

In the design of the valves themselves the leakage question is the important point demanding attention. Leakage may arise through distortion of the valve by the steam pressure, by unequal ex-

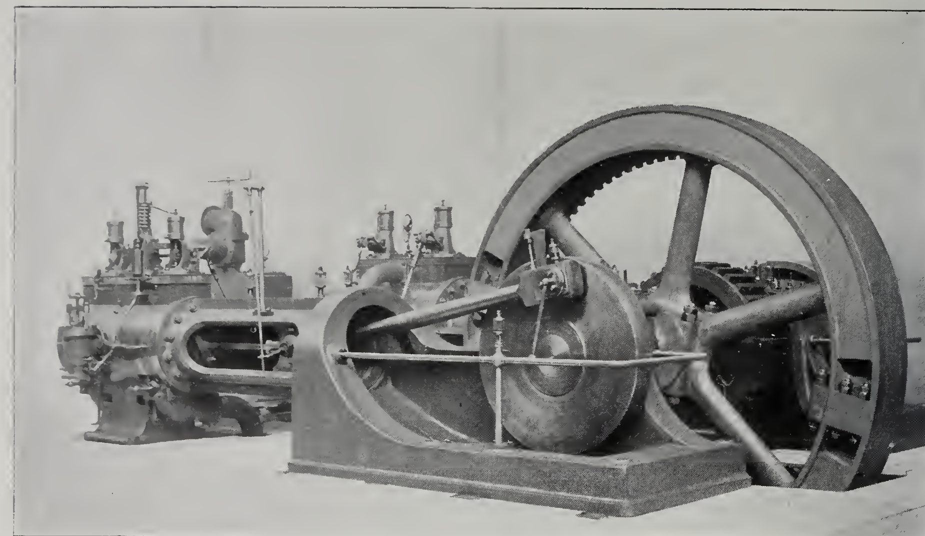


FIG 5.—COMPOUND ENGINE, WITH DROP-VALVE GEAR, MADE BY MESSRS. MARSHALL, SONS & CO., LTD., GAINSBOROUGH, ENGLAND

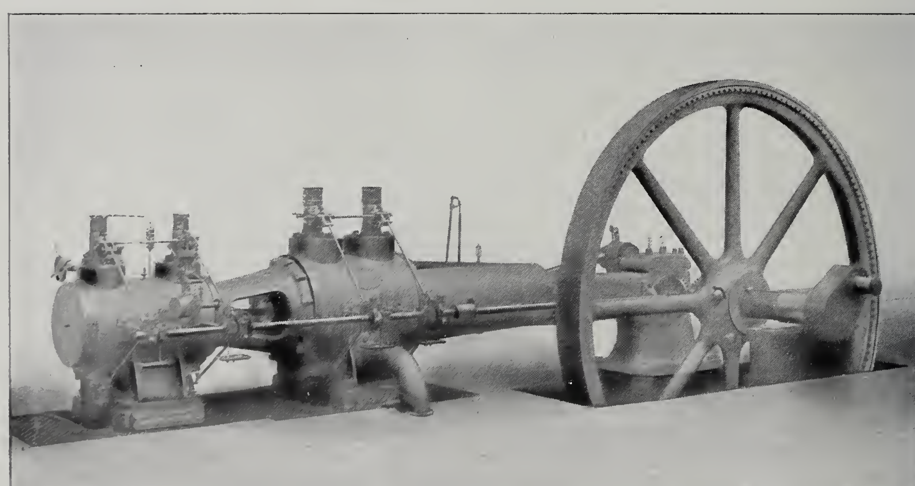


FIG. 7.—TANDEM-COMPOUND DROP-VALVE ENGINE BUILT BY MESSRS. DAVEY, PAXMAN & CO., LTD., COLCHESTER, ENGLAND

pansion of the valve and seat, or by the presence of indentations or foreign matter on the faces. The valves must be made sufficiently strong to resist distortion, but at the same time they should carry no superfluous metal. The narrower the faces, the more the valve approaches to a condition of perfect equilibrium when closed; but, on the other hand, a narrow face is soon worn. The writer has found the width of valve seats given in the accompanying table to coincide with the average practice of some good makers. The width given is half the difference between the outside and inside diameter of the faces, and the actual width is qualified by the fact that the angle of the valve seat is 45 degrees.

Largest Dia. of Valve	Width of Seat
6 in.	1/8 in
8 in.	3-16 in.
10 in.	5-16 in.
12 in.	3/8 in.
14 in.	7-16 in.

The material employed for the valves and seats is sometimes phosphor bronze or similar alloy, and sometimes cast iron, the latter being found to give very good result, although the valve is somewhat heavy. Whatever metal is chosen, it is important that both valve and seat should be cast from the same mixture, so that their ratios of expansion are alike. The valve should be as short as possible so that the effect of the expansion is confined to a short length of metal, and at the same time the clearance volume is less, the shorter the distance between the seatings. Sometimes four-seated valves are used in order to reduce the lift, and in such designs it becomes highly important to bear the above points in mind in order to avoid leakage, which is possible past four faces.

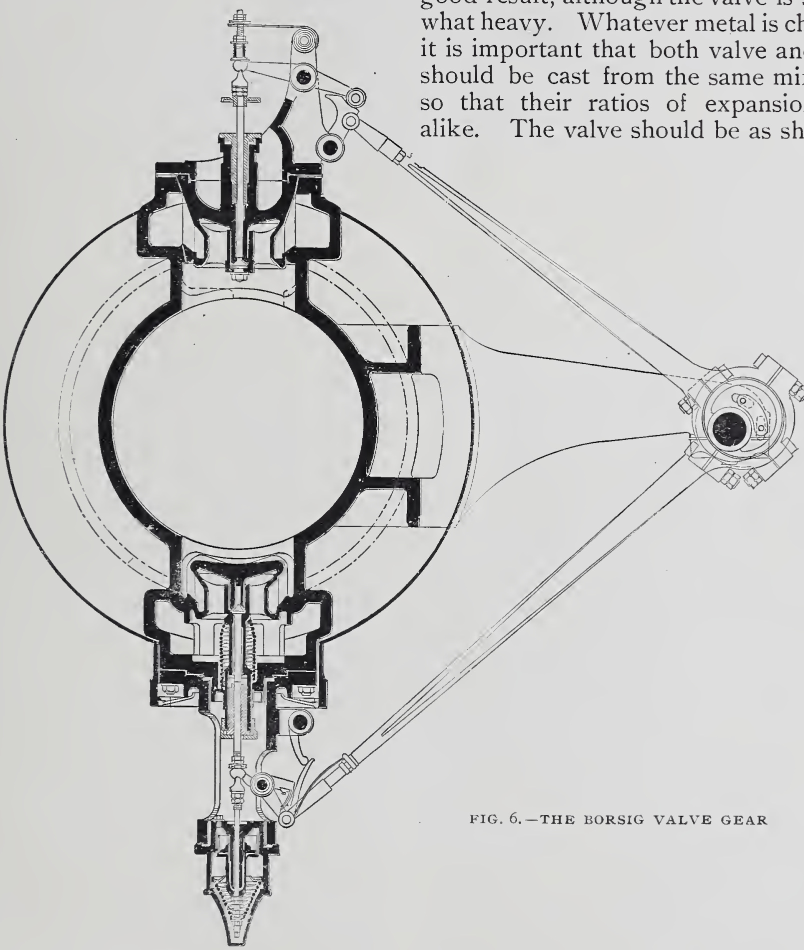


FIG. 6.—THE BORSIG VALVE GEAR

The advantage of the drop valve in engines using superheated steam is that the lubrication of the valve faces presents no difficulty under the high temperature; there is no rubbing action on the valve seat, but simply a gentle beat on the face. Lubrication is thus hardly necessary, since abrasion of the faces can under no conditions occur. It is to this fact that the drop valve undoubtedly owes much of its present popularity; and had the practice of superheating not been revived within recent years, it is doubtful whether in Great Britain the drop valve would have been adopted to any great extent.

Having thus glanced rapidly at the main considerations which must be met if successful operation is to be obtained, it may be interesting to illustrate a few examples of modern drop-valve engines by well-known makers.

The valve gear shown in Fig. 3 is by the well-known firm of Sulzer Brothers, of Winterthur, Switzerland, and is an interesting example of the use of rolling levers and four-seated valves. The gear in question is applied to the low-pressure cylinder of a horizontal triple-expansion engine. It will be noticed that the cut-off is fixed, and both steam and exhaust valves for one end of the cylinder are driven from one eccentric; the steam valve therefore closes at some point after half stroke. The motion is transmitted from the eccentric to the steam rolling lever *B* through the medium of the oscillating link *A* whilst the exhaust valve rolling lever is directly driven. The function of the link *A* is, of course, to reverse the diretion of the motion from the eccentric, so that when the exhaust is rising, the steam valve is closed, and *vice-versa.* The gear is well designed, and the lubricating arrangements have been thoroughly thought out.

Fig. 4 shows an engine made by Messrs. Robey & Co., Ltd., of Lincoln. The steam valves are of the double-beat type, and are closed by the spring dash-pot, the time of release being varied by the governor from the commencement of the stroke to about 7/8. The exhaust valves are of the sliding grid-iron type, and are operated by eccentrics directly connected to the valve spindle. The slides are placed horizontally at the bottom of each end of the cylinder. They afford an excellent natural drainage for the cylinder and as they are four-ported the travel is small.

Fig. 5 illustrates a coupled compound non-condensing engine by Messrs. Marshall, Sons & Co., Ltd., of Gainsborough. Both steam and exhaust valves are of the vertical lift-type, the steam valves being fitted with trip gear, whereby the cut-off is from the beginning up to 5/8 stroke, according to the load. The exhaust valves are operated by cams and rollers and have a constant period for the opening and closing.

The valve gear made by Messrs. Borsig, of Berlin, is illustrated in Fig. 6. Both steam and exhaust valves are driven by eccentrics, and the steam valves are provided with trip gear. The tripping finger *F* is under the control of the governor, and it is clear that as the upper end moves to the left, the tail piece of the catch lever is lifted out at an earlier period of the descent, thus adjusting the release of the catches to the load. The catches engage when the eccentrics actuating the steam gear are near the extreme throw, and consequently the striking velocity is very low. The exhaust gear consists of an intermediate lever carrying a roller which runs upon the inclined and curved face of the valve lifting lever.

Messrs. Davey, Paxman & Co., Ltd., of Colchester, also are makers of drop valve-gear engines, and Fig. 7 shows the gear side of one of their tandem compound engines with trip gear on both high and low-pressure cylinders, the catches in the high-pressure cylinder being under governor control, whilst the degree of expansion in the low-pressure cylinder is controlled by hand.

Current Topics

LOOKING back to a period of about four years ago, it is difficult to realise the panicky state of mind into which the directors and shareholders of submarine cable companies were thrown by the reports of successful transatlantic wireless telegraphy at that time. There were cool heads then, of course, who pointed out that the displacement of submarine cables by the wireless system was not even a remote possibility; but as is usual in panic times, many cable shareholders lost their heads and disposed of their holdings at a sacrifice. It is very interesting to note the equanimity with which this subject of wireless telegraphy is now discussed by those same people, as exemplified in certain remarks of the Chairman of the Eastern Telegraph Company at its last half-yearly meeting in London. Among other things, he said that, while holding the view that wireless telegraphy will not compete with long-distance submarine telegraphy, yet there are certain places where wireless telegraphy can be usefully employed, and he cited a case in point in the Azores, where some of the submarine cables now touch. Portugal has long desired that some of the outlying islands should be placed in telegraphic communication, but, owing to the nature of the sea bottom and the landing places of these islands, they are not considered suitable places to make the connection by cable; neither would the traffic warrant the expenditure for a cable. It is therefore intended to connect the points by a system of wireless telegraphy, to be worked in connection with the submarine cable system. This and similar uses of wireless telegraphy are the ones which have been consistently advocated in these columns.

NEARLY every writer on wireless telegraphy from its inception has called attention to the fact that the term wireless, as applied to electric wave telegraphy, is a misnomer, inasmuch as wires are still somewhat extensively used in its operation; but it remained for a more recent, and evidently a cynical, writer to assert that the term telegraphy, as applied to this system, was also a misnomer, because he had known cases where two ships had tried for an hour to say to one another that they had nothing to say. This, however, is rather a severe fling at wireless telegraphy, for while the art has well-defined limitations and is not yet by any means perfected in all of its details, it has nevertheless reached a point when it can truly be

said to be of much practical utility in places where wire telegraphy cannot well be employed. Perhaps the greatest error that has been made in the past by the foremost worker in wireless telegraphy has been in attempting to obtain results beyond the utmost present capacity of the apparatus; in other words, time has been wasted in trying to make the child walk before it can creep. And this appears to be an error from which it is difficult for some people to depart, for, notwithstanding that the elaborate efforts of the past four or five years to bring about successful transatlantic wireless telegraphy have, up to the present time, seemingly failed, it is now stated that work in this particular direction must be delayed pending the making of arrangements for opening up wireless communication between Italy and South America, a distance of 6400 miles. The inutility of this method of procedure may be better understood when it is considered that the wave energy emitted by the wireless transmitter decreases at least as the square of the distance, from which it is easy to calculate that the chances of successful wireless transmission between Italy and the Argentine Republic are four times less than between Europe and North America. In the meantime, however, it is interesting to know that the Italian Government has fixed the rate for wireless messages between Italy and South America at four pence per word, which is so much done.

THE Japanese, like the Chinese, have no alphabet in the ordinary sense, every word in their written language being represented by a separate character. In telegraphing in these languages, therefore, about 10,000 words are selected, and figures ranging from 1 up to 9999 are allotted to each word. Each word of a message to be transmitted by telegraph in these languages is then first given its proper number by the telegraph clerk, by means of a dictionary which has been prepared under the authority of the Government. These numbers are then transmitted by the Morse alphabet, and, when received, the message is translated back into the Chinese or Japanese characters by reference to a corresponding dictionary. This method of telegraphing is, of course, cumbersome, but it could be employed by those nations as the equivalent of a cipher code in warfare, with very little probability of any foreign nation deciphering it. For prompt telegraphic communication, the English language is probably used by the Japanese. For the reasons stated, however, it is obvious that the telephone must be a great boon to nations possessing such extensive alphabets, since by this system each word is transmitted as it is spoken.

WHILE in command of the U. S. S. *Monterey* in the Asiatic fleet last year, Commander William H. Beehler adopted a simple method of estimating distances by which officers and men became very expert. According to an account given by Commander Beehler in a paper printed in the Proceedings of the United States Naval Institute, this method consists of getting two lines of sight, one with the right eye and the other with the left eye. The observer simply sights with his right eye along the right forearm extended to its full extent and pointing with the right forefinger at the distant object. He then closes the right eye and sights with the left eye, holding the right arm and head rigid as before. In this case the second or left-eye line sight will point to the right of the object first sighted with the right eye, a distance equal to one-tenth of the distance that the said object is from the pointing finger of the observer's right hand. These two lines of sight intersect at the point of the forefinger of the right hand, and with lines joining the two eyes and lines joining the object with the point to which the left-eye line of sight shall have moved to the right, form two right-angled triangles which are opposite and similar. The eyes are normally 2.75 inches apart, and the right forearm fully extended will bring the point of the right fore-

finger 27.5 inches from the right eye; the proportion of 10 to 1 exists between the base and altitude of the smaller right-angled triangle, and the same proportion exists between the larger triangle in which the base is the estimated distance that the left-eye line of sight shall have moved to the right of the object and the altitude is the distance of the object from the intersection of these two right-angled triangles.

An example of the practical use of this method will be clearly understood. While at Chefoo the *Monterey* was required to take position 300 yards from the *Monadnock*. The *Monadnock* was 55.5 feet beam, and when directly astern of the *Monadnock*, observers pointed at the mast of that vessel and found that the left-eye line of sight moved to the right a distance equal to a beam and a half of the *Monadnock*, a distance equal to 55.5 feet plus 27.75, or 83.25 feet, making the distance of the *Monadnock* 832.5 feet. By pointing to the port edge of the after turret of the *Monadnock*, a point just 34.5 feet from the edge of the starboard rail at its greatest midship section, the distance was found to be 900 feet when the left-eye line of sight pointed to the right at a distance such that the *Monadnock* might just fill the space between that point and the position of her starboard rail, a distance of 90 feet. It was required that the *Monterey* should be 300 yards or 900 feet from the *Monadnock*, and every officer and man on board could at any time determine the distance. The distance which the left-eye line of sight moves to the right of the previously observed line of sight with the right eye is only an estimate; and if that estimate is erroneous, the distance will have been estimated thereby with an error ten times that of the first estimated lateral displacement. If this lateral error amounts to 10 yards the estimated distance will be 100 yards in error, but such an error will not be made by those who are expert in this method. A little practice, especially in observing distances of objects of known dimensions, will make the error in the estimated lateral displacement of the left-eye line of sight very small, much less than a foot, and therefore invariably give the distance within 5 or 6 feet of the true distance, even when the object, such as a steamer at sea, may be 2 or 3 miles distant.

In discussing the case of the large locomotive and the fireman who serves it especially in the light thrown upon it at the recent convention of the American Railway Master Mechanics' Association, the *Railway Age* says that it is possible to draw the following conclusions:—First, that in recent years poor material has often been employed for firemen. Second, that the poor firemen are most extravagant in coal consumption when working wide fireboxes. Third, that the irregular firing of wide fireboxes has resulted in leaky tubes and cracked sheets. Fourth, that the capacity of a large locomotive is easily limited by the endurance of the fireman, whether good or bad Fifth, that the economic size of locomotives may in some instances have been exceeded on account of the limitations of the fireman's strength. It is easily possible for the fireman to affect unfavourably the coal performance with wide fireboxes, even when he is endeavouring to do his best work. The rules relating to the privileges due to priority of service of firemen have had a tendency to place the youngest and most unskilled men on the large engines with wide fireboxes, because the older men prefer the lighter work on the smaller locomotives. Although the rate of wages paid firemen is higher than that received by skilled mechanics, who have spent several years in learning a trade, or of clerks who are perhaps better educated, yet the fireman's service is no longer attractive to a good grade of men on account of the laborious work required in handling the large amount of coal consumed per trip by large locomotives.

It has been shown that, as now operated, the wide firebox is not superior to

the narrow one in economy of fuel, and coal consumption must be nearly proportional to the horse-power developed with either type of boiler. As the large locomotives have a horse-power capacity nearly double that of the medium-sized engines used a few years ago, the amount of coal to be handled per hour when these engines are working at normal capacity must be twice as great. While the fireman may be able to handle this amount of coal for the first few hours, he cannot keep up the work uniformly for the whole trip. The Master Mechanics' report on automatic stokers emphasised this fact in explaining the conditions under which the machine stoker will prove most valuable:—"When the engine is loaded to maximum capacity the automatic stoker will not tire, and consequently it will enable the engine to carry maximum pressure all of the time and get the full benefit of the tractive power of the engine over a long, continuous trip; this cannot be done by hand-firing." The power of the large locomotive is thus limited by the fireman in his failure to maintain uniformly full boiler pressure, due to the limitations of his physical endurance. So far as irregular firing results in failures of the boiler and firebox, to that extent does the fireman determine the mileage service of the engine, for such failures require it to be laid up in roundhouse or shop, and there is a loss due not only to cost of repairs, but to the limited service obtained on the road.

If the above statements be considered with relation to the size of locomotives as measured by their coal consumption per hour, it would appear quite possible, continues the *Railway Age*, that a given tonnage could be handled by a locomotive of medium size which would burn economically the same amount of coal used by a large locomotive on the same trip. Having reached the limit of the capacity of the fireman to shovel coal enough to maintain uniform boiler pressure, is it a profitable move to build locomotives still larger, and in some instances has not the economical size of hand-fired locomotives been more than reached? With oil fuel or with a machine stoker it is possible to force steam production and maintain uniform pressure beyond the maxium of present consumption, and it is only by the use of such measures that the continued growth of the locomotive may be justified.

It has been pointed out many times, says the London *Engineer*, that practical engineering is not pure science. The designing and construction of a good bridge, or a good engine, represents only half the work that has to be done. No one of importance or influence works as an engineer, or makes bridges, or roofs, or engines, for the fun of the thing. These are made to be sold. That is the great fact that the professor and the technical schoolmaster ignore. They cannot teach anything about the price of materials or labour. They regard that aspect of engineering either with a languid interest or unqualified disgust. They hold that such matters do not come within their province, and it may be conceded that in a sense they are right. But the result is none the less unsatisfactory. Over and over again the same statement is made by the manufacturing engineers whenever education is discussed, that they cannot obtain men who know what work ought to cost. Under a proper system of technical education the young engineer would be taught not only how to make designs, but how to estimate the price at which they can be carried out—not necessarily with minute accuracy; yet the mere fact that the subject formed part of an examination paper would open his eyes to its importance. It is quite as necessary that the engineer should know what the eyed link in a suspension bridge chain will cost as to be certain what stress can be put on it with safety. It is not less important that he should clearly understand how much money must be expended to drive a hundred 30-foot piles, as it is that he should know how many

blows of a monkey each will require to send it home, and what load it will then carry. The man who thoroughly understands the difference between good and bad riveting has mastered only the rudiments of his subject, unless he is also competent to say what any seam will cost under all possible conditions.

The man—college trained, or shop trained, or both—who has not grasped the fact that cost price is a thing of supreme influence will design a bridge which may be excellent, perhaps, in all respects but one, and that one shortcoming, if he could but see it, is fatal. The man who designs a bridge which must cost £10,000, while one costing £8000 would meet every possible requirement of the traffic, simply wastes £2000 belonging to somebody else. Economy in fuel, in steam, in water, in electricity, are all taught. But no one ever seems to dream of teaching economy in labour, or in money, or in materials. It is true, of course, that weight is kept down by the designer. But it is scarcely ever found that his motive has been a desire to reduce first cost. Lightness is the result of stress calculation, and nothing less. At this moment we have the constructing engineer—the manufacturer—and the designing engineer—the man who plans, and schemes, and draws—and the pity of it all is that, whereas these men should play into one another's hands, they are for the most part antagonistic. It is hard work at any time to induce young men to consider money values, and the propagation of the theory that estimating, or learning the value of materials and labour, is a branch of education which it is waste of time to take up, is not calculated to smooth the path of those who insist on the importance of training every young engineer to lose no opportunity of acquiring information as to, at all events, the approximate cost of every portion of every bridge, roof, machine, or engine, with which he has to do. In the present day it is easy enough to get men who can design or superintend; it is next to impossible to find any reasonably young man who can tell his employers what anything from a rivet to a girder, from a crank pin to a boiler, ought to cost. Until that prominence is given to the work of estimating which it deserves, the education of engineers can never be regarded as satisfactory or complete.

Engineers everywhere know Professor Unwin, or at least know of him through his writings, and will be interested, therefore, in the announcement made a short time ago that he would retire from active work at the Central Technical College of the City and Guilds of London at the end of the college session. The monthly journal of the college,—*The Central*,—has commented on the event as follows:—"It is with the very deepest regret that we have to record the approaching retirement of Professor Unwin at the end of the present session. The college will thereby lose a professor of whose eminence and ability it would be presumptuous for us to speak, and whose teaching and personal influence will always be gratefully remembered by those who have been privileged to work as his students. Making, as it does, the first break in the original professorate of the college, a professorate which has raised it in a period of a little less than twenty years from small beginnings to its present position, the change is an important event in the history of the Central. * * * Professor Unwin was appointed to the professorship of civil and mechanical engineering by the institute at the opening of the college early in 1884, and served as Dean from that date until midsummer, 1895, and again during the last two sessions. In 1901, when the reconstituted University of London added a faculty of engineering, Professor Unwin was made University Professor in that subject. Some idea of the progress of the college during this period may be gathered from the fact that in 1877, the first year in which diplomas were awarded, there were only nine granted four of these being to

students in Professor Unwin's department. Last year the record number of sixty diplomas was reached; the total number of diplomas which have been gained since the beginning of the college is 521, and in addition 395 certificates have been awarded; many more special students have worked in the college laboratories. At the present day there are over 300 regular students, whilst 80 students from the Royal College of Science attend a special course of lectures and laboratory work in electrical engineering at the Central. * * * The present occasion affords a favourable opportunity for old students to show that they have not forgotten their professor and their college. After due consideration, it has been decided to commemorate Professor Unwin's long connection with the Central by founding an 'Unwin Scholarship' at the college. This will constitute a more lasting memorial than any merely personal tribute, and is the form which we feel sure Professor Unwin would prefer that any testimonial should take. The arrangements are already in the hands of an influential committee, and it only remains for every old student to assist by contributing as liberally as lies in his power."

TWO cylindrical movable dams across the river Main in Germany are among the noteworthy engineering features of the City of Schweinfurt. According to an account of them, given by A. Steens in the *Scientific American*, they were built partly to render the stream above them navigable and partly to divert the water for power utilisation. As the river is subject to heavy floods, a type of dam that would permit a very rapid discharge of the freshet water had to be designed, and the cylindrical form, arranged to roll upward above the flood level, was adopted. To demonstrate fully its practicability, the first dam was constructed across a secondary branch of the river at Schweinfurt, with a total length of 59 feet and a diameter of 13 feet. The satisfactory operation of this led to the construction, across the main branch, of a second dam, 115 feet long and about 6½ feet in diameter. Briefly, it is a hollow cylinder of sheet steel, on each end of which is a toothed wheel which meshes with an inclined rack built in each abutment. The dam as a whole consists first of a sill upon which the cylinder in its lowermost position rests. This cylinder extends from shore to shore. When lowered, it effects a rise in the river of 6½ feet.

THE first dam designed differed materially from the second in the method of raising the cylinder. It was designed to be hauled from its lowest position by cables on each end. In the second dam, the driving mechanism is all located at one end. When the downstream level of the water rises, the pressure would have a tendency to lift the gate. The cylinder itself is watertight, to prevent the freezing of the water which might otherwise collect in it. Still an interior pipe is provided in the smaller dam, open at each end of the dam, but shielded by its interior location from the cold. This pipe is filled with water to secure greater stability. The racks in the case of the second larger dam are placed at an angle of 45 degrees. The cylinder, in its lowest position, rests on a sill of oak and the tightness of the dam at each end is provided for by a band of leather around the periphery. The pressure of the water holds the leather against the sill. The cylinder of the larger dam also is watertight except in two chambers in the upper part at each extremity. When the downstream water level does not rise more than 3 feet or so above the bottom of the dam, the weight of the cylinder is sufficient to counterbalance the pressure; but when the water level rises above this limit, the water enters the two chambers, giving the cylinder added stability.

THE adoption of electric locomotives by the New York Central & Hudson River Railroad for its suburban train service opens the way toward the solu-

tion of many interesting problems. It is scarcely exaggerating matters to say that, if the opportunity is seized and held from the beginning of operation by the engineering and auditing officials of the company, the most exhaustive and valuable data yet secured in heavy electrical suburban service will be forthcoming. To go a step further, the company will have it in its power to contribute knowledge of the highest value to the engineering world, and it is to be hoped that the financial results of electric operation will be made public, as in the case of the Manhattan Elevated Railway in New York It is probable that the cost of repairs upon the electric locomotives will be considerably below the figures which express the maintenance expenses of the best passenger steam locomotives now operating upon the road. This advantage of the electric machines has not been generally noted up to the pres ent time. The steam locomotive is a most useful, rugged and reliable piece of rolling stock, but it is heavier than the equivalent electric machine; complicated by numerous valves, pipes, links and running gears; and handicapped by an enormous boiler and heavy tender. Finally, it is accurately balanced for but one speed, and is subjected to the terrific pounding strains. There is no reasonable doubt that the engineers at present running fast trains by steam power will notice a remarkable smoothness and comfort in operation as soon as they begin to drive the new machine, —a condition which is a sure indication of reduced wear and tear. This is mostly to be charged to the uniform torque of the electric locomotives during and throughout every revolution of the driving wheels.

The majority of electric locomotive repairs will probably be cures of minor troubles with the electromagnetic switches, brushes, compressors, brakes and other easily accessible parts. The space taken up in the repair shop will be less than that required by many of the steam machines, and the handling of the various parts by hoists and cranes ought to be an easy matter in comparison with the care and expense of handling the massive bulks of steam locomotives. Altogether there are many reasons to believe that the maintenance problem will be much simplified by the new machines, and the reduction in such expenses will be worth studying by everyone who has access to the operating figures.

In the earlier days of American steel-rail making, as told by Captain Robert W. Hunt before the American Institute of Mining Engineers, the steel was poured into ingots which would make but two 30 ft. rails not exceeding 60 lb. weight per yard—giving a mass weighing, say, about 1400 lb., and of a section about 12-in. square. To-day the ingots are about 22-in. square, and weigh more than 4000 lb. Of course, the interior of the larger ingots must remain hot and liquid longer than that of the smaller ones, and from this condition arises the steel-rail maker's *bête noir*—segregation of the metalloids and piping of the steel. The smallest-sectioned ingot will pipe, but with the increase of its size there will be also increase of the interior cavity. This tendency existing and being well known, it would seem that, rather than being ignored, especial care should be exercised to avoid the evils arising from it.

In the earlier days, too, after the ingot had been rolled down to a bloom of 6 or 7 inches square, all cracks were carefully chipped out of it. Such defects could not be welded up by subsequent working, but if cut out to the deepest point, particularly if the forming of sharp corners was avoided, the steel would, when further rolled, draw from the bottom up; and so if the cavity was not too deep, a sound bar or rail would result. This chipping was performed under a steam hammer. Later, if, while the bar was passing between the rolls of the rail-

mill, defects were discovered, the rolling operation was suspended until they also could be chipped out. Then, again, great care was taken that the steel bloom should not be overheated. There were from six to eight blooms, each of a size to produce one rail, charged at one time into a heating furnace, and skilled workmen attended to their heating, and turning over on the bottom of the furnace, so that all sides should become of an equal temperature. If from any cause this man made a mistake and sent his steel to the rolls in an unsatisfactorily heated condition, the head rail-roller, or some other mill official, rejected it and it was returned to him for further treatment. This meant that more or less care was exercised on each and every rail; but the daily production was, when viewed from to-day's standpoint, quite small. The first departure was to cease chipping the blooms at the rail-rolls—the next, to make it one continuous process from the first blooming of the ingot to the finished rolling of the rails. This procedure stopped the intermediate chipping of the blooms under the steam hammer, and carried with it the rolling of more than one length rail, that is, the rolling of a mass of steel large enough to produce more than one rail length, and the subsequent sawing of this into two or more rails. This new method of rolling had been made possible by the introduction of more or less automatic machinery; and the daily production of a given rail-mill increased very rapidly. But unfortunately the care which it was possible to bestow on the making of each individual rail decreased in an even greater ratio—an effect which was inevitable.

In the old days, a Bessemer converting-house was equipped with two converters, each of about 5 tons capacity, which were gradually enlarged to 7, 10, 15, and even 20 tons, and additional converters were added. Of course, the size of the house, blowing-engines, cranes, etc., were all proportionately increased and the development of the plant has proceeded until, instead of about 12,000 tons of ingots per month coming out of one converting-house, more than 70,000 tons per month are now produced. There is more and larger machinery and, it has been said, such a large output is the best evidence that everything must have been running smoothly. That is true so far as mere production goes; but the speed and momentum are against the exercise of the proper kind of care necessary to produce sound ingots of the highest quality of steel. This is old-fashioned doctrine, but it is true.

Speaking of "the ideal foreman" for the machine shop in a recent address before the National Metal Trades Association, Mr. William Lodge said, among other things:—"The ideal foreman will cultivate the habit of seeing with his eyes continually. There is nothing that makes a foreman more lame than the absence of this trait in his make-up. Every step he takes in every minute of the day, if this habit is cultivated, will show him some point that can be bettered or improved, and he should not only make use of it himself, but, if possible, educate every man under his charge to cultivate the same habit. It is deplorable to have a foreman who is an excellent mechanic and all right in every other particular but utterly without this trait, and I have no doubt every one of us has seen such men. I remember having at one time a man who was so excellent a mechanic that I thought there was no possible chance of making a mistake in giving him charge of the shop. Within a month, however, I found that he was incapable of handling it, and almost for no other reason than that he was unable to see; he had not cultivated the habit of seeing. He would walk through the shop from end to end, swinging his rule, while the work in all directions was crying out to be taken hold of, and the man unable to see it. In a little while such a man would have utterly destroyed the profit-making capacity of a shop, and he would have done it innocently. Now I knew

there were good things to be had from this man, and studied very hard how to get them; so one day I said to him, 'Here, Jim, take this piece of work and sketch out for me the very best means of doing the best work in the least possible time and in the best possible manner,' and, sure enough, I found I had struck his gait, and at this employment he was worth a fortune. But this very man twice attempted to run a business for himself and twice lost every dollar he had, and all because he had not cultivated the habit of seeing. A foreman who cultivates the habit of seeing discovers where the plant is lacking or where his department is lame, and that is the point where certain parts that are necessary to complete the work he has in hand are not forthcoming. The good foreman will endeavour to get these. If he finds that the capacity of the shop will not give them to him, he will sit down at the place where they are being made, put on his thinking cap and try with all his might to see whether he cannot make that particular piece in one-half the time, and very often this will result in its being produced in even less time than that. This is the kind of foreman that is especially and particularly valuable, providing that while he is engaged at the work above mentioned he does not forget all else under his charge to such an extent as to let it suffer.''

INSTRUCTING locomotive firemen in the chemistry of combustion is likely to be a profitable bit of enterprise on the part of railway companies. According to *The Railroad Gazette*, the coal inspector of a prominent American railway, who claims a wide acquaintance among the enginemen of different roads throughout the United States, says that while he has found these men, without exception, to be thoroughly competent in their knowledge of the mechanism of their locomotives, fully 90 per cent. of them are seriously lacking in a knowledge of coal and the requirements for its successful combustion. Appreciating this, several lines have for some time had in their employ fuel inspectors whose duties are not only to supervise coal shipments from the collieries and make sure that the companies are getting what they are paying for, both as regards quality and quantity, but who at intervals deliver lectures to the enginemen and firemen, telling of the composition of coal, the processes going on in the firebox during combustion, and how coal may be burned economically. Excellent results are said to have already come from this practice.

As in line with the luxuries of modern American office building equipment, Mr. James H. Wells, in a paper read before the American Society of Mechanical Engineers, mentions the case of one tall building recently erected in New York in which every room is heated and ventilated by means of an indirect system operated by fans. This is an extraordinary case, however; it is usually impracticable on account of the cost of installation and the amount of room taken up by the fans, heaters and ducts. In the New York Stock Exchange the air is warmed in winter, and by means of an immense refrigerating plant cooled in summer. But these are all special methods, and the great bulk of the heating is done by the direct method,—that is, radiators under windows in the rooms. In many buildings there are refrigerating plants installed both for cooling the drinking water and for making ice which is sold to the tenants.

IN an article printed some time ago in one of the railway periodicals, and referred to in the volume of Foreign Abstracts of the Institution of Civil Engineers, Mr. R. W. Western calculated that the mechanical energy required to run a car one mile is equal to that absorbed by fourteen stoppages, so that if the car stops four times in a mile, and the operating costs amount to 4*d*. per mile (wages excluded), the sum to be debited to stopping should be 0.22*d*.

In this calculation it is assumed that the weight of the car is 6 tons, and that its speed is 10 miles an hour. Taking the concrete case of the City and South London Railway, it is calculated that the cost of stopping the train is 0.747*d*. These figures do not include losses due to standing. Each train cost 6.86*d* per minute of actual running, so that the loss of 17½ seconds at each station amounts to 1.983*d*. From the figures of the Liverpool Corporation Tramways it is calculated that £35,000 are annually expended in stopping the cars. A passenger who stops a 6-ton car moving at 10 miles an hour causes an expenditure of energy of 45,000 foot-lbs. If he stops it both on entering and leaving, this amount is doubled, and as only 6600 foot-lbs. are required to carry him a mile, it follows that he could have been carried over 12 miles for the same expenditure of energy as he demanded in stopping the car twice. The suggestion is to accentuate the use of regular stopping-places or to charge a passenger extra for stopping specially at any other place.

THE general conclusion drawn by Mr. Edward Atkinson, of the Insurance Engineering Experiment Station at Boston, from the teachings of the recent disastrous fire in the city of Baltimore, is that as yet no fireproof buildings have been constructed for general purposes, either as shops, warehouses, hotels, office buildings or other purposes; nor will there be such a fireproof building so long as combustible materials are used within for the finish and flooring of the building, or, perhaps, so long as combustible material is used within for desks, tables, shelves, chairs and other furniture. It is hopeful, however, to know that there are now numerous types of metal-clad or incombustible material for inside finish quite as ornamental as any kinds of wood, many of them much less costly, and that office furniture of incombustible material is being made on a large scale. It is perfectly conceivable that a practically fireproof office building may be constructed and so occupied as to be proof against fire generated within, or even against a conflagration without. The window spaces and wall spaces of an office building may be so planned that fire-resistant shutters may be recessed between an inner and outer wall at the side of each window without affecting the stability of the construction, these sliding shutters closing the window spaces automatically when tripped or set in motion by a fusible link exposed upon the outside of the wall between the windows.

THE danger which seems to be least considered in the planning of office buildings, department stores and the like is the open stairway, the open hallway, the open elevator and other flues pervading the building from top to bottom. In factory practice the vertical hazard is regarded now as a greater danger than the hazard of large areas. The large areas necessary in the conduct especially of textile work, sometimes of several acres, often of one acre on one floor, may be sufficiently well guarded by automatic sprinklers to be considered very safe; but the condition in these rooms is wholly different from that of the department store. In the factory a small quantity of very combustible material is spread over the machines away from the walls under such conditions that the water from the sprinklers can cover nearly every point where fire can exist or spread, other precautions being taken in the few instances where a fire may lurk in the hollow space within the machine. It follows that in all but one known instance water from the sprinklers has overleaped the fire and has held it until the mill fire departments have extinguished it with relatively very small loss. In only one instance has a fire gone over the stock faster than the sprinklers held it, leading to a considerable loss; but in that instance the cause was probably due to the natural effort of the fire department to put on water from the pumps and hydrants a little too soon, drawing water away from the sprinkler service.

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PRESIDENT OF THE EDISON ELECTRIC ILLUMINATING COMPANY OF BOSTON

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AUXILIARIES OF A WAR FLEET

WITH SPECIAL REFERENCE TO RECENT ADDITIONS TO THE BRITISH NAVY

By Archibald S. Hurd

CIVILIANS are apt to forget that in modern warfare the mere possession of ships, guns and men is not everything. Behind the fighting ships must be an immense organisation, distributed between the headquarters of the fleet and its local depots, and even beyond this there must be an expensive squadron of auxiliary vessels which can be sent to the men of war if the necessities of a campaign compel them to fight a long distance from their home ports or a permanent base.

Great Britain has more coaling and supply stations than probably all the other nations of the world combined; they link the Seven Seas together. In order to render them immune in case of raids by stray cruisers of the enemy vast sums have been spent upon defensive works. In spite of this advantage in coaling and store depots in all parts of the world, the British authorities have been among the first to recognize the necessity of providing a fleet of auxiliary ships for service either in the protected anchorages or with the fleet at some temporary base which may have been created to serve the ends of a particular warlike movement.

This is the main lesson which the British Admiralty has drawn from the Spanish-American War. The events of this contest are too recent to require recapitulation. As soon as war was certain, the Congress of the United States voted a large sum of money for the purposes of the coming campaign, and of this no small part was spent in acquiring and fitting out auxiliaries for the fleet. In large measure this was the secret of the success which attended the operations of the men of war of the United States. But for the foresight of the United States Navy Department, it would have been impossible to conduct the operations off Cuba, and especially off the Philippines, with such conspicuous success. Every dollar that went in auxiliary vessels,—store ships, repair ships, hospital ships, colliers of various types, distilling ships, refrigerating ships, etc.,— was well spent.

It is too often forgotten that in these days much careful organisation and wise expenditure on non-fighting vessels

ONE OF THE 12,000-TON COAL FLOATING DEPOTS IN PORTSMOUTH HARBOUR. WHEN COMPLETED THERE WILL BE A NUMBER OF STEAM CRANES RUNNING ALONG ON RAILS ON THE DECK SO AS TO PERMIT RAISING COAL FROM ANY PART OF THE HOLD

must be sanctioned if a fleet is to achieve victory. Men of war are merely moving gun platforms. During war, a careful administration does not leave a land fortress without possibility of replenishing its stores. A warship is practically an isolated fort. If circumstances permit, it will return to its base for fresh food, water, stores and ammunition, but the conditions of a war may render it unwise to withdraw ships from duty, and it is then that the auxiliary ship fills the need and enables the fighting ship to remain at its post, it may be thousands of miles from its nearest base for supplies. What lies behind a fleet in action is almost more impressive than the men of war themselves.

Taking a fleet approximately of the strength of the British squadron now in Chinese waters, Admiral Sir Cyprian Bridge lately estimated the amount of the supplies it must receive within a given period in time of peace, premising that " the difference in the supply of a given naval force in war and in peace is principally that in the former the requirements of nearly everything except provisions will be greater; and consequently that the articles must be forwarded in larger quantities or at shorter intervals than in peace time."

The figures obtained are most significant. Admiral Bridge's assumption is that the number of men to be supplied is about 10,000, that the number of days during which each ship is under way, and therefore burning coal at a much more rapid rate than when she is stationary, is not, in time of peace, more than six or seven in the month, and that the quarterly expenditure of ammunition is constant. Consequently he found that on this basis " the tonnage requirements of the squadron and its auxiliaries for a full six months' period would be about 74,000 without fresh water. As, however, the ships would have started with full store-rooms, holds, and bunkers, and may be expected to return to the principal base port of the station at the end of the period, stores for four-and-a-half months' and coals to meet twenty weeks' consumption would be sufficient. These would be about 6750 tons of stores and ammunition, and 46,000 tons of coal."

This is " without fresh water," however, " a commodity which ships have never been able to do without, and which they need now in higher proportion than ever." Sir Cyprian Bridge calculated that the requirements of the squadron would be little less than 30,000 tons in six months, of which the ships, without adding very inconveniently to their coal consumption, could distill about one-half; " but the remaining 15,000 tons would have to be brought to them and another 1000 tons would probably be wanted by the auxiliaries, making the full six months' demand up to 16,000 tons."

In time of war even these totals would be greatly increased, the only constant amount being food and other similar stores, while as for coal, " calculations founded on the experience of manoeuvres shows that in war time ships would require nearly three times the quantity used in peace." Coming to ammunition this officer stated " in case we were at war a single action might cause us to expend in a few hours as much as half a dozen quarterly peace allowances." The six months' peace allowance of ordnance stores and ammunition for such a squadron is 1140 tons; the requirements for war would probably be ten times as great.

Supplies on this scale cannot be kept permanently in store at a base. Coal deteriorates rapidly and the losses through frequent handling are considerable. As Admiral Bridge remarked,—"If any one doubts this deterioration, it would be well for him to examine reports on coal and steam trials. He will be unusually fortunate if he finds so small a deterioration as 10 per cent." The figures of the late Commander-in-Chief of the British-Chinese squadron effectively illustrate the large field of employment that there must be in time of war.

Or again, turning to repairs, what was the record of the American repairing ship *Vulcan* during the Spanish war? She supplied thirty-one vessels with extra engine parts, material and tools. Twenty-six vessels were repaired,

and a number of other repairs were made also on guns and their equipments. The *Vulcan* also rendered inestimable services in connection with the raising of the *Maria Theresa* and did the greater part of the work of temporarily repairing the vessel preparatory to her transfer to one of the navy-yards of the United States. In fact, throughout the war the auxiliary ships of various types added immensely to the fighting efficiency of the American fleets, which, but for their aid, would have had to make frequent journeys to some permanent or temporary base.

One danger of the auxiliary was illustrated throughout the campaign. Each of these vessels adds to the responsibility of the commander-in-chief and, if the speed is slow, the assistance which such craft can render may be purchased at too great a price. If an auxiliary becomes a drag upon the fighting ships, its benefit is considerably discounted, because in modern men of war, even armoured ships which are to lie in the line of battle, speed,—the highest attainable,—is a tactical advantage of no mean importance. Having made, it may be, some sacrifices in fighting power to compass a high rate of steaming, it is unwise, to state the case very mildly, to throw away the advantage by tacking on to a squadron auxiliaries which cannot maintain its average speed. The auxiliary must not be detailed for service haphazard, but must be selected with care, so that its radius of action and speed may be nearly as possible similar to that of the fighting ships with which it is to act.

The British authorities have recognized that fleet auxiliaries may be divided into two classes, and it is important that the distinction should be remembered. The wisdom of their decision is revealed in the story of the American preparations for the war against Spain. Had the Navy Department at Washington foreseen war, some of the auxiliaries which had to be hurriedly provided would have been obtained in advance, but on the very eve of hostilities it was proved that it was possible to fit out many of the auxiliary ships which it is desirable to have, while others could be chartered practically ready for use. Consequently there is good reason in the decision of the British authorities to divide fleet auxiliaries into classes,—

1.—Ships which cannot be hastily provided in sufficient time to act with the fleet on the very outbreak of war.

2.—Vessels which can be readily obtained and, if any alterations are necessary, can be refitted in a very short time for their war duties.

In the first class are included a number of colliers with adequate transporting arrangements, though possibly not as many as would be required, repair ships equipped to carry out all the most important repairs, some distilling ships, etc. In the other class are embraced an immense number of vessels such as telegraph ships, which can be chartered from cable companies at almost any moment; hospital ships, which can be readily transformed from ordinary liners; auxiliary cruisers for miscellaneous service, which the merchant fleet can supply, and others. The British Admiralty policy has been set out by Lord Selbourne, First Lord of the Admiralty, with commendable lucidity. He has remarked, among other things,—

"It is often assumed in argument that there is no doubt as to the number of auxiliary vessels that will be required in war, or as to the exact type they should be, or as to the use to which they could be put. As a matter of fact, this is not so, except in so far that the Board have fixed exactly the number of auxiliary vessels that, according to their present experience, would be required in time of war.

"In all organisations there are two classes of instruments which will be required in time of war,—the class which cannot be improvised, and which must be fully created in time of peace, and the class which can be improvised speedily on the outbreak of war if proper preparation has been made in time of peace. This is true of auxiliary vessels.

"Certain auxiliary vessels can, if every preparation has been made beforehand, be taken up from the mercantile marine immediately on the out-

break of war. There are others which must be created in time of peace. Although hospital ships belong to the former class, they may be very useful also in time of peace with large fleets, as has been exemplified in the case of the *Maine* (the generous gift of Mr. Baker, a citizen of the United States), which is now serving in the Mediterranean. As regards the latter class we (Great Britain) and all other nations are still in the experimental stage.

"In the case of colliers the policy of the board has been, by continual chartering, to induce private owners to build as many vessels as possible which are thoroughly suited for the needs of the fleet. I will take another case as an example, depot ships for destroyers. A different class of ship is required, according as the destroyers are or are not acting from a fixed base; opinions differ also in the latter case as to the exact use to which these vessels can be put. One class of depot ship is being prepared for the flotillas at the home ports, and the *Leander* is being prepared as a depot ship for the destroyers in the Mediterranean. From this experience we shall learn more clearly what is exactly required; but if the new *Scout* class is a success, these depot ships should not be wanted for them to the same extent.

"Again, in the case of distilling ships, one has been bought and fitted which should be on service within the year, and experiments have been made with others; but obviously it will be far better if, by improvements in the boilers, ships are able to distill their own water, and can be made independent of auxiliary distilling vessels."

It is on these lines that large sums have been and are now being spent by the British authorities, and it is probably not too much to say that in this respect they are ahead of any other naval department in the world.

Before proceeding to deal further with the provision which the Admiralty are making, opportunity must be taken to refer to one famous auxiliary ship of the British fleet, the hospital ship *Maine*, mentioned by Lord Selborne above. She did good service during the war in South Africa. She was chartered by a number of Americans and placed at the disposal of the War Department, and proved an immense boon to the large number of suffering soldiers who were cared for on board. When the war closed her owners, with unexampled generosity, gave her, as she stood, completely furnished as an up-to-date hospital ship, to the British Admiralty.

Since the gift was made, the *Maine* has been attached to the fleet in the Mediterranean, and from all sides have come expressions of appreciation of the kindly thought and good-heartedness which placed this magnificent vessel at the service of the officers and men who are called to serve in a climate which is very trying to health. Malta fever and its ravages are known to everyone familiar with the British fleet. The *Maine* is a large ship of 4500 tons, and is admirably fitted for the humane purpose to which she has been put.

Coming to the details of the auxiliary fleet which has been provided by British authorities, it is impossible to do more than mention some of the older types, such as the following, descriptions of which are appended:—

Vulcan.—Torpedo depot ship, built at Portsmouth dockyard, England, in 1889. Displacement, 6620 tons; indicated horse-power, 7200, giving 17½ knots; forced draught, 12,000 horsepower and 20 knots; steel deck, 2½ to 5 inches thick, and armament of eight 4.7 quick-firers, twelve 3-pounders, one boat gun, sixteen Nordenfelt machine guns, and six torpedo tubes; six second-class torpedo-boats, two countermining barges, four steamboats, two of them conveying 14-inch torpedoes. The *Vulcan* is fitted up as a floating workshop for repairing vessels, having lathes, foundry, smithy, hydraulic forge, press, etc. She has two hydraulic goose-neck cranes, something like those in the *Kearsarge*, capable of lifting 20 tons through a height of 40 feet. Her crew number nearly 450. The engines were built by Humphrys, Tennant & Co., of Greenwich.

Wye, *Humber* and *Tyne.*—Single screw storeships. The *Wye* was built

at Sunderland in 1873, and displaces 1370 tons. The *Humber* was constructed at Hull, and is slightly larger; while the *Tyne* was built at the Low Walker yard in 1878, and has a dis placement of 3500 tons.

Hecla.—Repairing ship, built at Belfast in 1878. Has a displacement of 6400 tons.

Industry.—Storeship, built at Glasgow in 1901; displaces 1600 tons.

Nubian.—Coal depot, purchased in 1901.

Kharki and *Onward*, etc.—Small steam colliers.

There are many other small vessels, but this list may be said to include all the most important auxiliary ships which were in the British fleet prior to the recent direction of attention to the subject. The Spanish-American war effectually turned the thoughts of those concerned with the efficiency of fleets to this most important aspect of a necessary provision for keeping a fighting fleet at sea.

One of the greatest difficulties in modern warfare is the arrangement for the supply of coal to a fleet away from a base. Endless experiments have been made in the effort to evolve a type of ship suitable for the coaling of ships while under way; but though many expedients have been tested both at the home ports and in the Mediterranean, in no case has a completely satisfactory solution of the difficulties been arrived at.

Since these experiments were begun,—and they are still in progress,—increased attention has been turned to the question of using liquid fuel. It is, of course, recognised that coal can be shipped far less easily than oil; but, on the other hand, the British authorities have to walk warily, for whereas they have a practically unlimited supply of the best steam coal in the world, they have no oil fields upon which to draw.

It is said that deposits have been found in British North Borneo, but nothing very definite is yet known as to the value of the discovery. Experiment has been directed to oil as an auxiliary for spraying over coal, and it is recognised that it may be employed with much advantage. In presenting to the House of Commons his navy estimates for 1904-1905, Lord Selborne, the First Lord of the Admiralty, was able to state:—

"The experiments with oil fuel have continued without a day's intermission, and I think it can be accurately stated that in no country has greater attention been given to this subject or the experiments been more exhaustive. The progress has been slow, but sure; it is not a matter which can be hurried; the great difficulties connected with the satisfactory use of oil ships of war can only be overcome by patience and continual experiment; the experience gained with the *Mars* and *Hannibal* (battleships) in the Channel Fleet with their cylindrical boilers has been utilised in respect of the Belleville boilers of the *Bedford* (armoured cruiser, 9800 tons), which has now been commissioned for service in the Channel Fleet. Simultaneously with the experiments in the use of oil fuel the question of its storage and supply is being carefully studied."

In view of the progress which has been made in the utilisation of oil fuel, and the increasing number of ships, including vessels large and small, fitted for its use, provision has been made of supply ships at each of the home ports. Several old gunboats have lately been taken in hand and converted into oil tank ships with pumps for quickly transferring the liquid fuel to warships.

The progress which is being made in the adaptation of oil to the needs of the war fleet has not, however, caused the British naval authorities to abate for one moment their efforts to solve the difficulty of storing coal and then of rapidly transferring it to the bunkers of the men-of-war. If it were possible to adopt oil as the only source of motive power, it would be a simple matter to build storeships which would deliver it on board ships at the rate of 300 tons an hour; but unfortunately the British Admiralty can entertain no prospect of this solution of the problems of coal supply, because liquid fuel can never displace coal so long as Great Britain is entirely

dependent upon foreign sources of supply. Consequently, side by side with the oil experiments various expedients are being tested for the storage of coal, for the use of briquettes, for the equipment of colliers, and for the construction of self-propelled depots.

One of the most interesting vessels recently sent into the water is a ship which has been constructed by Messrs. Swan, Hunter & Wigham Richardson, Ltd., at their yard at Wallsend-on-Tyne, England. This craft is styled a floating coal depot, and has been built in conjunction with the Temperley Transporter Company, of London. It is the first vessel of this description that has been built. The vessel is intended to be moored in Portsmouth harbour, England, so that battleships and cruisers can come alongside,—one on each side of the vessel,—and be coaled at a very rapid rate.

The principal dimensions of the vessel are:—Length, 67 feet 9 inches, and depth moulded, 40 feet, and the coal capacity is 12,000 tons. There is a double bottom all fore and aft for water ballast, and a space of about 8 feet between the double bottom and the hopper deck, the hoppers containing the coal being above this deck. There are also two fore and aft bulkheads, leaving a complete trunk the whole length of the coal hopper for passing up the bags of coal. The coal is loaded into bags through chutes in the hopper deck, and there is a space on the tank top to stow a large quantity of coal, about 1000 tons, in bags ready to be put on board the war vessels. The machinery is driven in every part by electricity, there being a large electric windlass at each end of the vessel, and the electric lighting system is very complete, as is also the ventilating system. The boilers and pumping machinery and piping were supplied by the Wallsend Slipway & Engineering Company, Ltd., of Newcastle-on-Tyne. The electrical gear was made by Clarke, Chapman & Co., Ltd., of Gateshead-on-Tyne, and Mechan & Sons, of Glasgow, fitted up the ventilating plant.

As this vessel is unique, some account of the method in which she will be utilised may be appended. She is equipped with twelve Temperley transporters entirely operated by electric machinery, and the hoppers are fitted with eighty coal chutes for filling the bags without shovelling. The depot provides a method of storing large quantities of coal afloat under the most favourable conditions for rapidly loading it into bags without shovelling, and for discharging it on to war vessels by means of the transporters.

The difficulty hitherto experienced of getting Welsh steam-coal in hoppers to run or flow through openings in the bottom or sides thereof, owing to the large lumps of coal bridging over and blocking the openings when under pressure, is satisfactorily solved by the new system, as the Newcastle *Chronicle* pointed out at the time of the launch. The advantages set out are:—The rapid coaling of war vessels, the rapid filling of bags without shovelling and with safety to the men, accessibility, mobility, great storage capacity, no valuable quay space occupied, no breakage of coal in loading, no delay in starting coaling, coal stored under cover. In addition, this depot can coal two or more vessels at once, can coal direct from collier to war vessel, and, as the bags are filled and assembled on smooth, level floors, there is very little dust.

The hull of the depot is in the form of a large, flat-bottomed, straight-sided vessel with bluff, rounded ends, and it is subdivided into seven compartments. The five compartments contain the ten hoppers, the after end compartment is for the electric generating machinery, and the forward end compartment is appropriated to crew accommodation and stores.

Two longitudinal bulkheads, 9 feet apart, in the middle of the vessel divide the five holds into ten hoppers, and form a clear passage-way between them, giving access through the numerous openings to the space under the hoppers, and providing a clear exit up through which the bags of coal are hoisted by the transporters at any point in the length of the depot. The bot-

tom of the coal hoppers is raised above the floors of the vessel, and provided with 240 trap-doors and 80 movable chutes for tapping the coal from below into bags without shovelling, the flow of coal being regulated by means of gates worked by hand-levers. The coal dust arising at the chutes is drawn off through a system of air-tubes by means of electric fans and delivered back into receivers in the hoppers.

The Temperley transporters, for loading and discharging the vessel, are carried on four travelling towers which run on a railway laid on the deck of the depot. The transporters have an overreach of 20 feet beyond the side of the depot, and lift their loads to a point 33 feet above water-level. Each tower carries three transporters, two of which are inclined, and may be used for loading the depot from a collier or for coaling a war vessel from the depot; the other is horizontal, and long enough to reach from the hatchway of a collier on one side of the depot to the deck of a war vessel on the other.

The output capacity of the depot is at least 500 tons an hour. Five hundred tons is somewhat in excess of the quantity which can, as a rule, be received by any two war vessels. It is reasonable to expect, under even ordinary conditions, a greater output than this, for if the transporters are quickly enough supplied with coal they are each capable of transhipping 60 tons per hour,—in all 720 tons. Making due allowance for delay, there seems to be no reason why an output of 600 tons per hour should not be aimed at as the normal rate of discharge, provided that the vessels being coaled can take the coal at this rate.

Many other important additions have been made to the coaling fleet, and large sums have been spent in improving and sheltering the shore depots. The Admiralty lately ordered two self-propelling colliers, known as 21 C and 22 C, which have been stationed at Devonport to wait on ships using that port. These two vessels, which were built and engined by Bow, McLachlin & Co., Ltd., of Paisley, have already proved themselves admirably adapted for their special work. Each of these vessels carries 600 tons in the hold, and can tow 300-ton barges alongside, which means that each vessel can deal with 1200 tons per trip. The appliances for transfer of coal from coaling craft to cruisers or battleships are so quick and effective that the coal can be transported at about 120 tons per hour. The expedition with which British vessels can now be coaled by any of the special craft is an undoubted advantage.

At the same time attention has been given to the provision of distilling vessels. The latest of these is the *Aquarius*, formerly the *Hampstead*, which was built by Messrs. S. P. Austen & Sons, at Sunderland, and launched in 1902. This is a steel vessel with a displacement of 2800 tons. Her principal dimensions are:—Length, 268 feet; beam, 37 feet 9 inches; and draught, 16 feet. Her engines, by Messrs. G. Clark, Ltd., of Sunderland, give a speed of 10½ knots an hour. She has cost, complete, £55,400, and is a most valuable addition to the fleet.

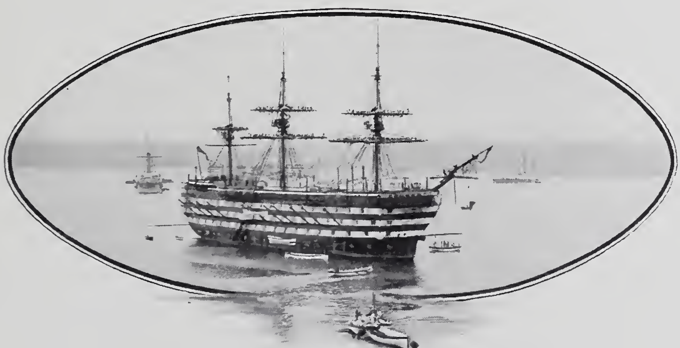
Another quite recent addition to the British auxiliaries of the fleet is the repairing ship *Assistance*,—a vessel of 9600 tons displacement, which has been built to the order of the Admiralty by Sir Raylton, Dixon & Co., at Middlesborough. She has a length of 436 feet, a beam of 53 feet, and a mean load draught of 20 feet. Her engines have been supplied by Sir C. Furness, Westgarth & Co. Under natural draught she registers 3000 indicated horse-power, giving a speed of 12 knots; but with the Howden system of forced draught she indicates a horse-power of 4200.

Her coal-carrying capacity is 1800 tons under normal conditions, and for the purpose of dealing with stray torpedo craft she has been provided with ten 3-pounder, quick-firing guns. Complete, she has cost £217,916, which is a large, but wise, expenditure, for the *Assistance* is a thoroughly up-to-date repair ship, with facilities for carrying out all but the largest repairs of a fleet when away from its permanent base, and

in time of war would prove of the most vital service. She is fitted with a foundry, and a large installation of machine tools of the latest type.

In addition to this vessel, several old men-of-war have lately been taken in hand, including the *Leander*, the *Warrior* and the *Audacious*, and equipped as "mother ships" for destroyers, so as to save these small boats from returning to the dockyards for all the lesser defects which they develop during their cruises. With the assistance of "mother ships" stationed at Portland, Felixstowe and Devonport, and in the Mediterranean, it should in future be possible for these craft to keep out of dockyard hands for long periods instead of popping in and out with considerable frequency, as has been the case in the past.

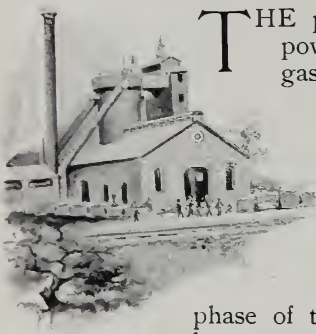
Mention has been made of a few of the more important additions which have been made to the auxiliaries of the British fleet, but as has been indicated already, these are merely those types of ships which it is believed cannot be hastily improvised on the outbreak of war, and behind this group of repairing ships, distilling vessels and colliers of various types lie the resources of the mercantile marine. Arrangements have been made for four more hospital ships to be ready within a short time whenever the Admiralty give the order, the fittings being stored ready for use, for as many cable ships to hoist the white ensign as circumstances may indicate as necessary, and for a number of storeships and colliers to be taken into the service. Thus it will be seen that the lesson of the Spanish-American War has been taken to heart very thoroughly by the British authorities.



FUEL GAS FOR INTERNAL COMBUSTION ENGINES

NOTES UPON ITS GENERATION AND USES

By J. R. Bibbins



THE present activity in power generation by gas engines has given prominence to the problem of generating efficiently and conveniently a fuel gas suitable for general use in gas engine plants. Although this phase of the power problem has not received as much attention as it deserves, it is at present a determining factor in the progress of the internal combustion motor.

For years the general conception of the gas engine has been that of a single-cylinder, rapidly-rotating, ill-smelling, barking little engine, suitable only for driving a coffee-mill or a launch. This elementary form has, however, been developed with such unprecedented rapidity that, while formerly the difficulty was in obtaining an engine of suitable design and capacity, now the difficulty is in supplying it with fuel gas. A decade ago an engine of 100 H. P. was considered phenomenal; to-day engines of 1000 H. P. are in successful operation, engines of 3000 H. P. and over are building, and capacities up to 6000 H. P. will be contracted for by responsible builders on demand. Mr. H. A. Humphrey, in a classical paper read before the British Association at Belfast in September, 1902, cited 327 engines, aggregating 182,000 H. P., in operation at that time in Continental Europe, thus averaging 550 H. P. per engine.

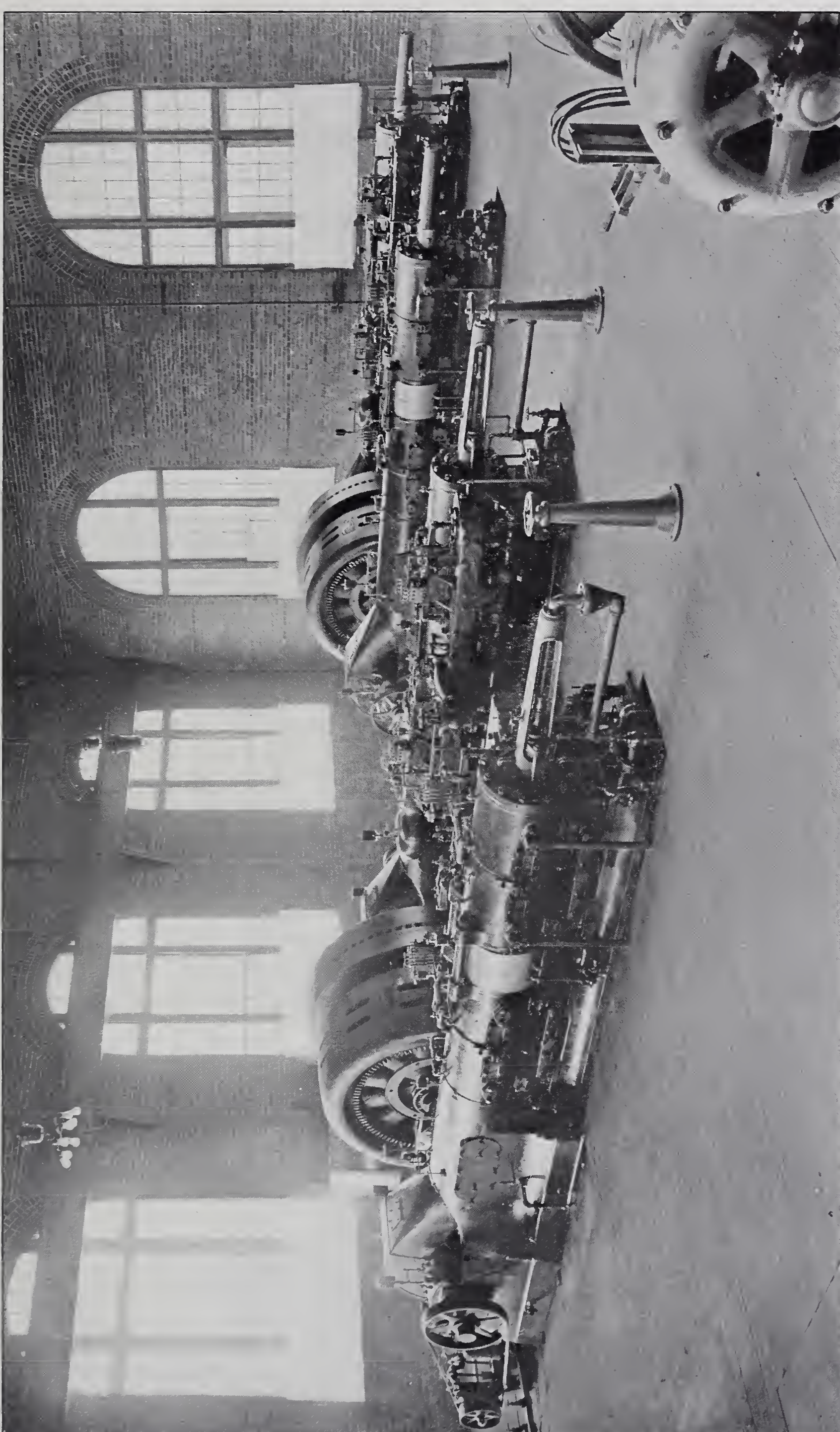
That this awakening of public interest in the internal combustion motor is in any sense due to other causes than intrinsic merit is not to be supposed in this enlightened age. High cost of fuel has been largely instrumental in directing attention to it. At the same time, its advantages over its principal competitor, the steam engine, are definite and actual; in point of higher thermal efficiency, in general compactness, in reducing the complexity of power plant operation, and in eliminating the losses incident thereto, the final net result being the reduction in the cost of power.

The provision of a fuel gas supply of proper quantity and quality to serve a modern power plant is distinctly a problem by itself. In scattered sections of both continents beneficent nature has placed at our disposal a most excellent power gas which needs only to be properly controlled and distributed to power users to make the gas engine an ideal means for obtaining power. Thus, in western Pennsylvania numerous plants are in operation which are entirely dependent upon this fuel. By reason, however, of the limited occurrence of natural gas, the manufacture of gas at the power plant becomes a necessity. In fact, for general power work it is the only effective means for bringing about the further introduction of the gas engine.

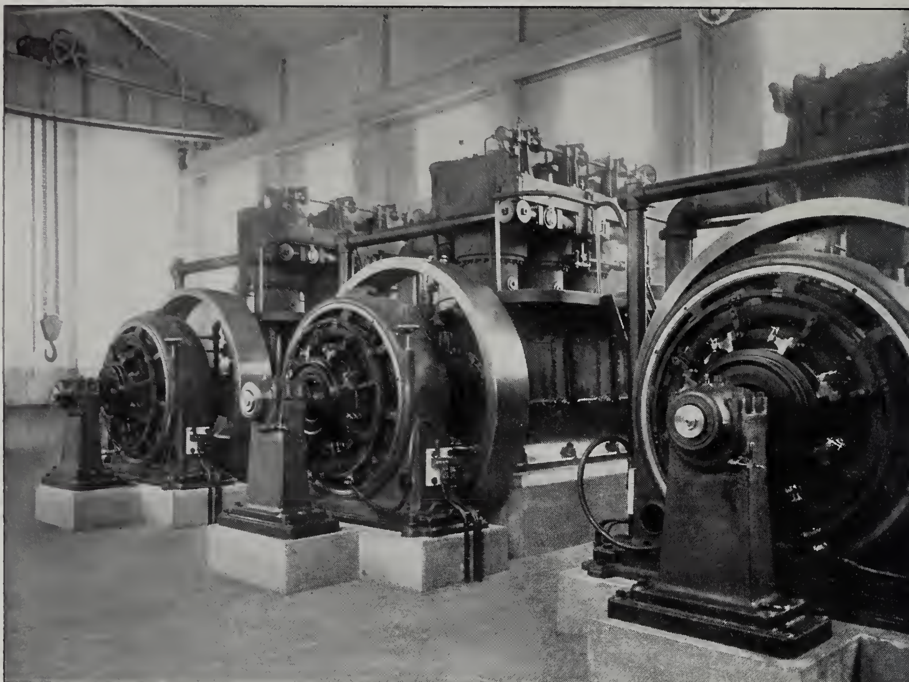
ADVANTAGES OF GAS FUEL

Considering a gas and a steam power plant *per se*, we find the two primary elements to be, in a sense, analogous, the gas generating process corresponding closely to the steam making process. There is a fundamental difference, however, between the two, which, in the case of gas, conduces to higher efficiency of production and distribution.

First, the generation of gas is simpler than that of steam. Less fuel has to be handled, and even this may be done



A TYPICAL GAS POWER STATION, AT THE ATLANTIC REFINING COMPANY'S WORKS, PHILADELPHIA, USING PRODUCER GAS AND FURNISHING ELECTRIC CURRENT FOR BOTH POWER AND LIGHT. THERE ARE FOUR 500-H. P. HORIZONTAL WESTINGHOUSE GAS ENGINES



A 500 H. P. WESTINGHOUSE GAS ENGINE EQUIPMENT AT THE WORKS OF THE WINCHESTER REPEATING ARMS CO., NEW HAVEN, CONN., U. S. A.

mechanically; less attendance is required to maintain a suitable product. The product is less sensitive to change of conditions or care on the part of employees. And the process is better adapted to meet varying demands from the engine end of the plant, particularly when holder capacity is provided.

Second, the losses occurring between boiler and engine in a steam plant, due to pipe radiation and leakage, are entirely absent in the gas plant; and, more important still, the "stand-by" losses are also to a great extent avoided. These form a large item of cost in a steam plant which is obliged to maintain a considerable portion of its idle boiler outfit under steam in order to provide sufficient steam storage to meet variable demands. In no process of power conversion is the storage of the working medium so readily accomplished as in the form of gas in a holder of dimensions proportioned to the character of the demand.

Third, high pressure may be absolutely eliminated in all parts of the plant, except in the engine cylinders alone, which may readily be designed of sufficient strength to operate with perfect safety under any conceivable pressure that may result from combustion of the gas.

Finally, cheap, low-grade fuels are, fortunately, suitable for the generation of gas of approximately the same quality as the more expensive grades of fuel, and at a cost, expressed in terms of useful work at the engine, far below the cost of a similar unit of power generated by the best steam plant. The gas generator and boiler furnace are quite analogous in their principles of operation. But the former has the overwhelming advantage, that the potential or chemical energy of the gas generated is ready for direct use in the gas engine cylinders instead of first undergoing a more or less inefficient transformation into the form of steam. Here is a direct exemplification of the business relations between manufacturers, middle-

men, and consumer. The elimination of the middleman secures lower cost of the delivered article.

THE IDEAL POWER GAS

Bearing in mind the present state of the gas engine and its entire dependence upon manufactured gas for its future progress, the following specifications suggest themselves:—

1.—Cheapness of generation is an all-important point which, unless attained, particularly debars gas power from competition with steam power. Unless a gas power plant can produce a useful horse-power upon a smaller consumption of coal than present high-grade steam plants, its adoption must be very limited, for the reason that fuel has become such an important item of expense in the management of power properties as to form the controlling factor in the preferment between competitive systems. In gas processes, it is usual that the one giving the highest conversion efficiency gives the lowest cost of power.

2.—Simplicity of operation of a gas engine plant is important. The smaller the number of distinct operations and auxiliaries to be taken care of, the less will be the cost of the process outside of the generator itself, particularly when the service of high-priced attendants can be dispensed with. There is at present a decided inclination in power gas work to introduce the by-product reclamation process, auxiliary to the main gas generation process. The proposition on its face is attractive. Tar, ammonia, and other compounds may be readily reclaimed in the bulk with suitable apparatus, and an almost infinite variety of valuable hydrocarbons by refining processes, all of which tend to secure a definite source of revenue to the gas plant in proportion to its output.

Although such reclamation processes are highly important in the case of concerns engaged in the manufacture of either crude or refined chemicals, it cannot be inferred that, for the average lighting or industrial power plant, it would be advisable to engage in these refinements of gas production which necessitate such radical departures from their fields of operation. In the broadest sense, therefore, the ideal system for general power work in the future will be that which presents the least complexity of operation.

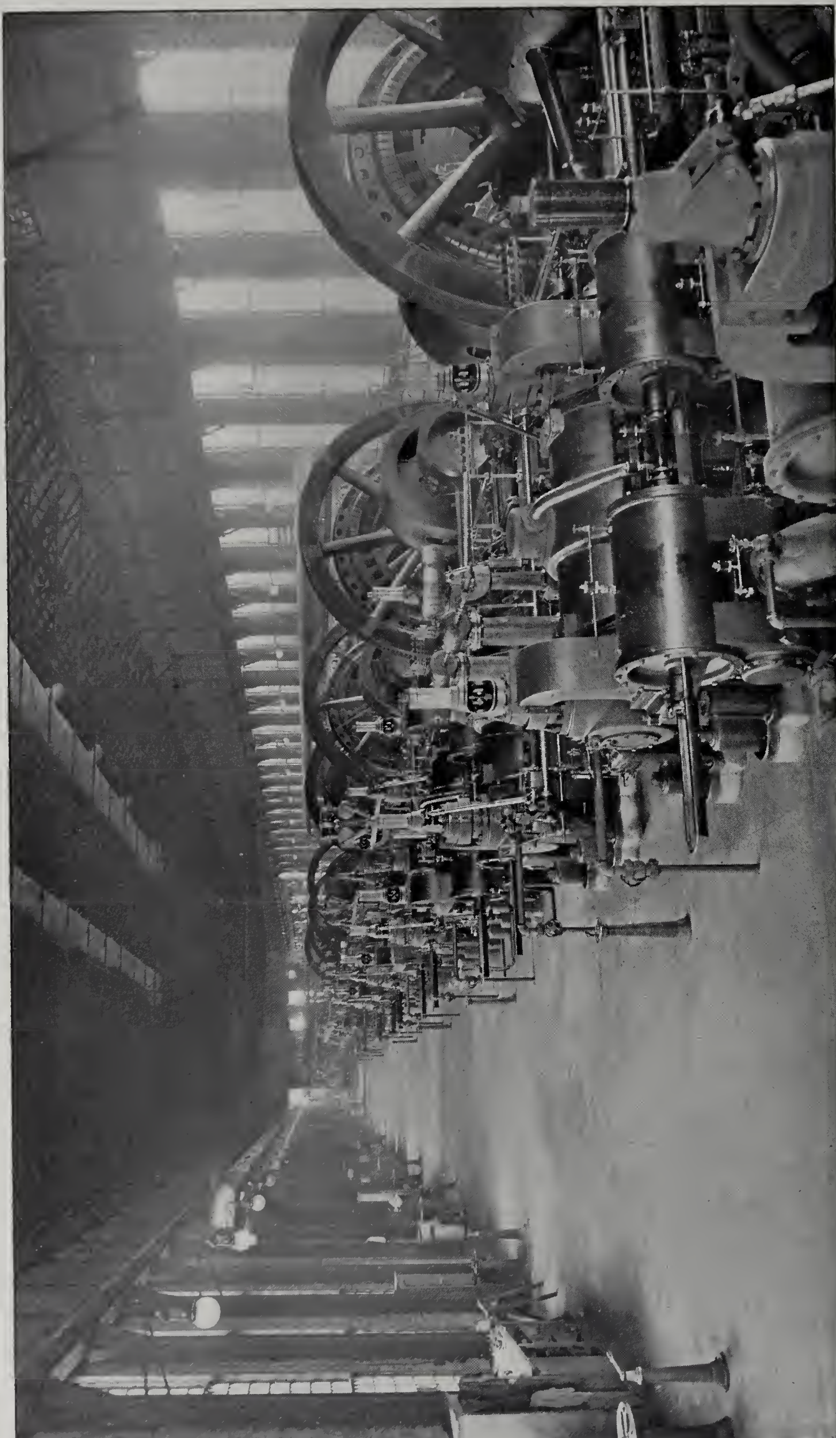
3.—A continuous process is most desirable. In securing a product of uniform quality, nothing is more important than to maintain as nearly constant as possible all conditions which may influence gas generation. It is evidently but a makeshift to employ a gas holder for any other purpose than to secure the necessary reserve capacity.

This feature is largely dependent upon the form of generator employed, as will be discussed later. It is sufficient to remark here that an ideal process should not involve the periodical alteration of conditions of gas generation, for the reason that the quality of the product is then so closely dependent upon the faithfulness and competence of employees.

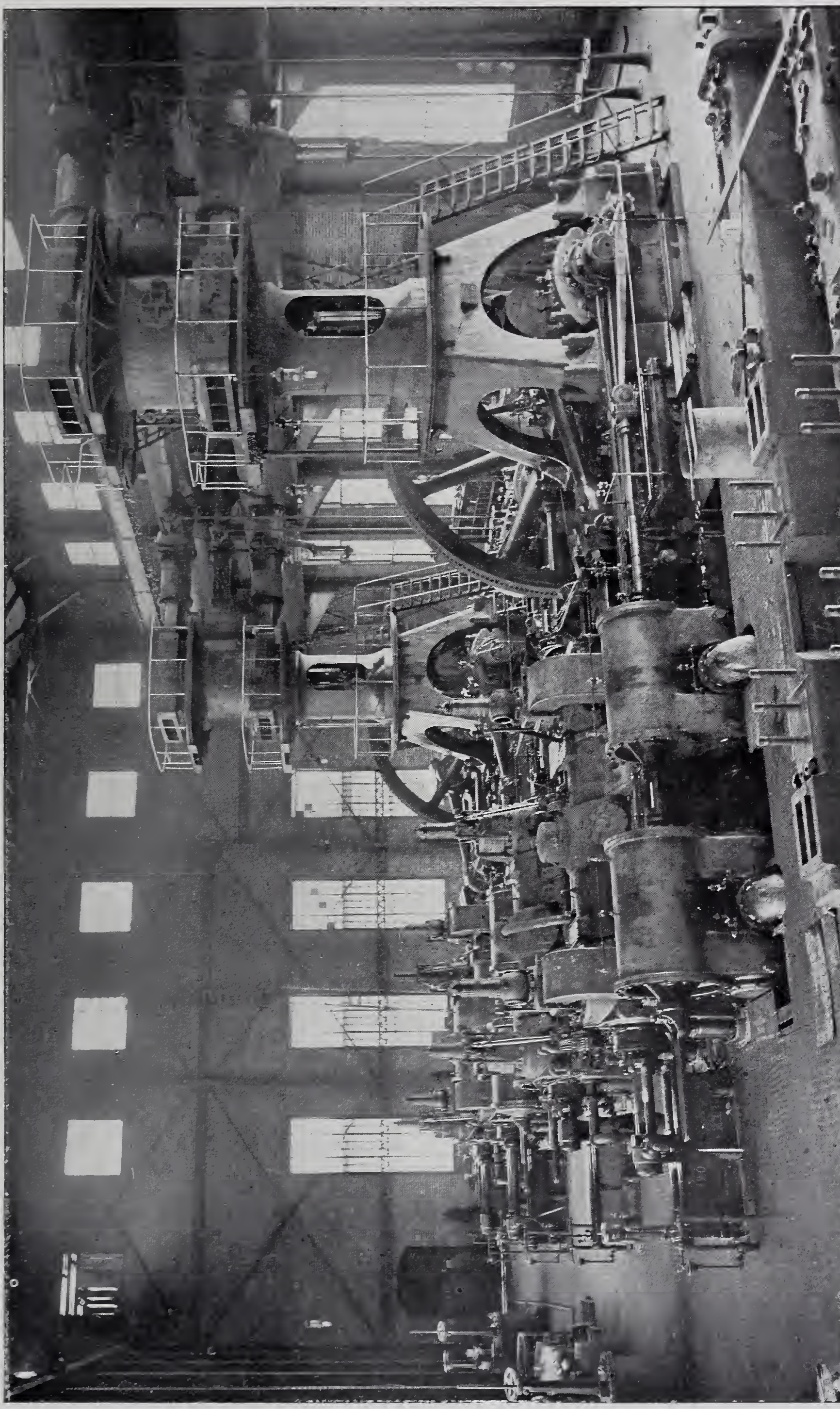
4.—A low percentage of hydrogen and of inert gases is to be attained. The latter desideratum simply secures a richer gas, with less volume to be handled or stored for a given power; the former reduces the flame temperature and speed of combustion, also permitting higher degrees of compression, with consequent increase in efficiency.

5.—Clean gas is an essential requisite. Gas leaving the generator should be free from all impurities that will cause trouble in the engine by scoring, choking or gumming valves and cylinders. In practice, this is difficult, but is approximated in a properly designed generator, where it is only necessary to remove from the gas fine ash and carbon dust held in suspension. The vital point is, that whatever form of fuel is used, the gasification should be wholly completed within the generator, not partially, as in many processes, thus making it necessary to provide and maintain elaborate auxiliary cleaning and scrubbing apparatus external to the generator.

In observing how closely the various power gases now available meet the standard of this ideal gas, it is clear that the producer gas process is alone susceptible to the development which is



EIGHT 1000-H. P. TWO-CYLINDER DOUBLE-ACTING KOERTING GAS ENGINES, DRIVING BOTH DIRECT AND ALTERNATING CURRENT GENERATORS AT THE WORKS OF THE LACKAWANNA STEEL CO., AT BUFFALO, NEW YORK. BUILT BY THE DE LA VERGNE MACHINE COMPANY, NEW YORK CITY



TWO OF SIXTEEN 2000-H. P. KOERTING GAS ENGINES BY THE SAME BUILDERS, DRIVING BLOWER CYLINDERS FOR THE BLAST FURNACES OF THE LACKAWANNA STEEL COMPANY. THE GAS ENGINE PLANT AT THESE WORKS IS THE LARGEST IN THE WORLD

impending. The problem confronting the gas engineer in the immediate future is not the selection of a process suitable for some particular cases or fields of usefulness, but, on the contrary, one of the broadest aspect, necessitating a process capable of universal application, such as producer gas has already proven itself to be.

COMMERCIAL POWER GASES

Let us hastily review the characteristics of the several power gases:—

Leaving out of consideration the limited and specialised use of highly inflammable and easily volatilised liquids, such as kerosene, gasolene, alcohol, naphtha, benzine, etc., the present sources of power for gas engine work are comprised in the accompanying table, which also shows their average calorific value and approximate distribution of constituents. The table was compiled by Mr. A. M. Gow, engineer of the East Pittsburgh Gas Works, and was presented in a valuable paper before the Engineers' Society of Western Pennsylvania, in May, 1903:—

distillation of crude petroleum or other liquid hydrocarbons, is at present somewhat of a special product and used mainly in enriching the leaner gases for illuminating purposes. A somewhat novel use has recently arisen in oil refining processes where a very rich oil gas, of 1000 to 1500 British thermal units per cubic foot in calorific value, is obtained as a by-product. This gas is exceptionally rich in combustibles, and forms an excellent gas for power work. A notable instance of its use is afforded by the 2000-H. P. power plant now operating at the works of the Atlantic Refining Company, at Point Breeze, Philadelphia. Four 500-H. P. horizontal, twin, tandem, double-acting gas engines, direct connected to polyphase alternating generators, operating in multiple, comprise the present installation. The use of oil gas constitutes a promising field; but at the present time very little has been done, except in special applications, such as cited above.

Bench or coal gas produced by distillation of bituminous coal in closed retorts is an excellent fuel for gas engine

TABLE I.—COMMERCIAL POWER GASES

GAS	Calorific Value B. t. u. per cu. ft.		Constituents—Per Cent. (Volume)			Constituents—Per Cent. (Volume)					
	Gas	Mixture *	Hydrogen H_2	Marsh Gas CH_4	Carbonic Oxide CO	Illuminants C_2H_4	Carbonic Acid CO_2	Nitrogen N_2	Oxygen O_2	O_2 for Combustion	Air for Combustion
Natural, Pittsburg	978	91.0	3.00	92.00	----	3.00	----	2.00	--	1.945	9.73
Oil	846	93.0	32.00	48.00	----	16.50	----	3.00	.5	1.615	8.07
Bench or "coal"	646	91.7	46.00	40.00	6.00	5 00	.50	2.00	.5	1.21	6.05
Coke oven	603	91.0	50.00	36.00	6.00	4.00	1.50	2.00	.5	1.12	5.60
Carburetted water	575	92.0	40.00	25.00	19.00	8.50	3.00	4.00	.5	1.05	5.25
Water	295	88.0	48.00	2.00	38.00	----	6.00	5.50	.5	.47	2.35
Producer, hard coal	144	68.0	20.00	----	25.00	----	5.00	49 50	.5	.225	1.12
Producer, soft coal	144	65 5	10.00	3 00	23.00	.50	5.00	58.00	.5	.24	1,20
Producer, coke	125	63.0	10.00	----	29.00	----	4 50	56.00	.5	.195	.98
Blast furnace	91	53.0	1.00	----	27.50	----	11.50	60.00	--	.143	.72

* Based upon theoretical air for combustion.

Values of combustibles·

CO = 320 B. t. u. per cubic foot.
H_2 = 320 " " " "
CH_4 = 1,000 " " " "
C_2H_4 = 1,600 " " " "

Natural gas occurs usually in proximity to extensive fuel beds; its use is, therefore, limited. It forms an ideal fuel gas, being extremely low in *N* and *H*, thus permitting high compression. It is absolutely clean.

Oil gas, obtained by the destructive

work, and approaches more nearly natural gas than any other form of manufactured gas. With the exception of oil gas, it is the highest incombustible. Bench gas, however, is generally the most expensive to generate, requires more care and labour, and is obtained

by a less efficient process than other gases. Furthermore, over half of the original carbon in the coal remains to be disposed of as gas coke, and elaborate auxiliary apparatus for cooling and scrubbing the gas and reclaiming by-product tar and ammonia must be maintained. Unless, therefore, the cost of bench gas delivered to the engine can be reduced by some means, it cannot readily compete with producer gas for general power work.

In a number of American illuminating gas works an electric light plant has been installed as an adjunct to the gas works, the two illuminants being marketed simultaneously. Gas engines furnish the power and draw their fuel directly from the works holders. By thus diverting a considerable proportion of the gas generated into the gas engine plant, the average output has been so largely increased that the cost per unit of gas has been reduced to such an extent as to render profitable the operation of the gas engine plant in place of the usual steam plant.

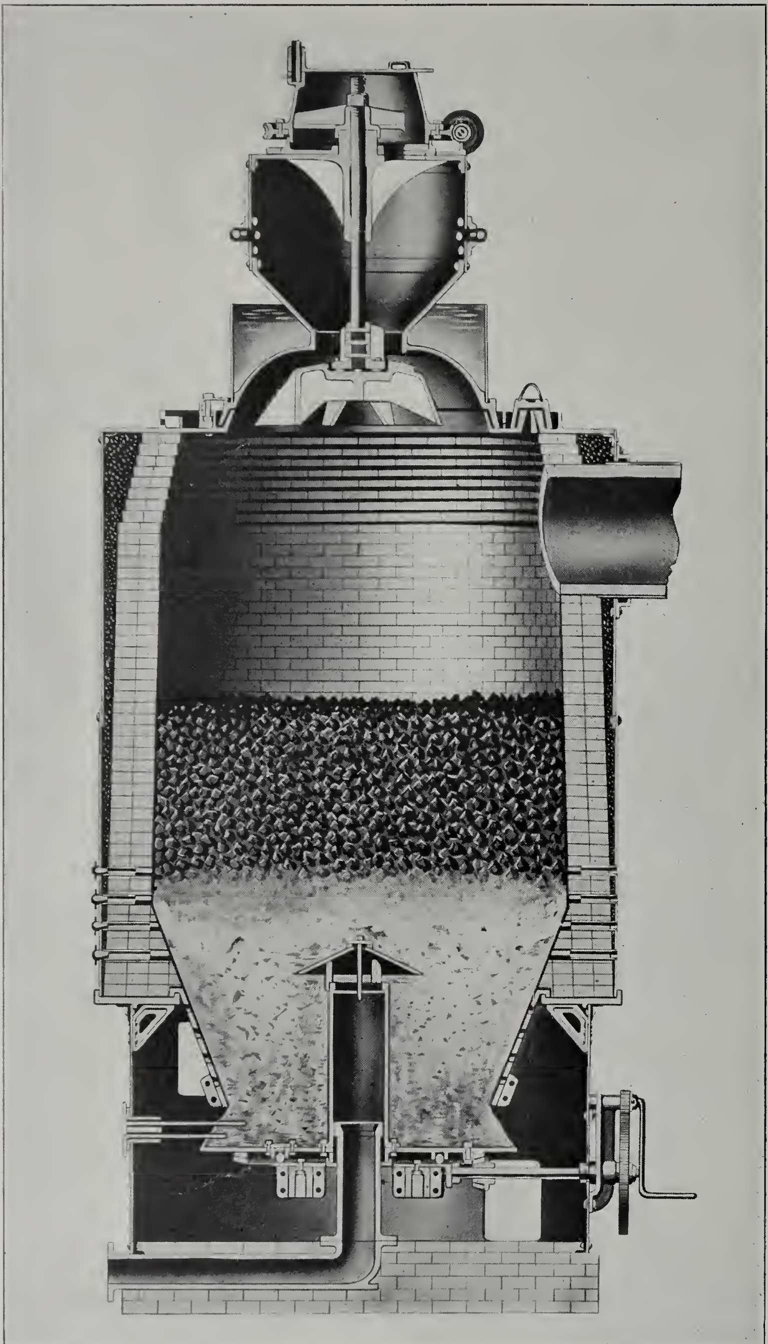
Coke oven gas is likewise a distillate from bituminous coal, and closely approximates bench gas in both calorific value and composition. Its general application is again restricted to bituminous coal fields, but practically unlimited quantities of the gas are there available which heretofore has been not only a waste product, but also a detriment to the health and vegetation in the coke districts.

Several coke-gas processes are now being exploited, having for their primary object the production of a high-grade metallurgical coke, suitable for blast furnace use, and incidentally the reclamation of the rich coal gas, part of which may then be used for firing the ovens, and the remainder in gas engines for power generation and electrical distribution. By working the ovens in a slightly different manner, a softer coke may be produced if desired.

Water, producer and blast furnace gases may be classed as the leaner gases suitable for power work, all being generated from carbon maintained at a high temperature by a blast of air. In straight water gas, a deep bed of coke, enclosed in a suitable brick-lined generator, is subjected to a blast of air from beneath until the internal heat has been raised to a high point. The reaction of C oxidising to CO_2 liberates heat. Steam is then blown into the coke bed, and is immediately dissociated into its constituent elements, the hydrogen escaping in free form, and the oxygen serving to further oxidise some of the excess carbon present to form combustible monoxide, which likewise forms a stable constituent of the resultant gas. As this operation of dissociation of steam absorbs heat or is an endothermic reaction, the internal heat in the generator is reduced.

The operation of water gas making is, therefore, an intermittent process, coke being first "blasted" with air to increase the temperature, and then "blasted" with steam until the temperature has again fallen to its lowest limit permissible. Usually the blast gas is wasted, after first being passed through a regenerator or "superheater," consisting of an enclosed checker work of brick, which absorbs from the passing gases a large percentage of their sensible heat. This reclaimed heat is then used in "carbureting" the water gas subsequently generated. As the gas passes through the checker work, crude oil is admitted, which is itself dissociated into oil gas upon striking the hot checker work, thus enriching the lean water gas with the desired quantity of illuminants.

A characteristic of water gas which, unfortunately, makes it rather unsuitable for power work, is its high percentage of hydrogen (nearly 50 per cent.). In illuminating work a high flame temperature is highly desirable, but in gas engine work it is a decided detriment if carried as far as in water gas, for the reason that it prohibits as high compression in the gas engine as would otherwise be desirable to enable the gas engine to operate at its highest efficiency. A large percentage of hydrogen in the gas largely increases the rate of flame propagation or combustion. On account of its low temperature of ignition



THE TAYLOR GAS PRODUCER, MADE BY MESSRS. R. D. WOOD & CO., PHILADELPHIA, PA. THIS CUT SHOWS THE AUTOMATIC FEED, THE REVOLVING ASH TABLE WITH SCRAPER BARS, ONE METHOD OF INTRODUCING THE AIR BLAST, AND THE ASH BED WITH THE COAL BED ABOVE IT. CONTINUOUS ROTARY FEED TYPE. CENTRAL TUYERE

it also introduces trouble in the gas engine from pre-ignition.

In water gas plants the heat lost in the periodical "blasting" of their generators with air may be very readily reclaimed by collecting this blast gas in a suitable holder and using it as a fuel gas in gas engines. It is approximately equivalent in calorific value to blast furnace gas (90 British thermal units per cubic foot). Although low in combustible constituents, it, nevertheless, could be used with advantage and economy in an auxiliary gas power electric station, either alone or mixed with a proportion of water gas, which would thus become less "snappy" and thereby better suited for use in gas engines. In fact, by this means a mixture may be obtained similar in many respects to standard producer gas.

Blast furnace gas is, again, a by-product, and formerly a waste product, of the ordinary iron ore smelting process. Singularly enough, although extremely low in combustibles (between 25 to 30 per cent.), it, nevertheless, is an excellent fuel for gas engines, for the reason that it permits of high compression and never contains tar or heavy vapours. It is, therefore, necessary only to remove the dust and scoria to render it suitable for use in engine cylinders. Its increasing importance as a fuel gas needs no emphasis other than the statement that the duty obtained from properly designed engines with blast furnace gas is quite comparable to that obtained with other manufactured gases. At least, it is obtained at practically no cost.

Coming, finally, to producer gas, it is found to be by far the most desirable of all commercial power gases, costing less to generate and requiring the least amount of auxiliary apparatus and consequent attendance. Any available fuel may be used to almost equal advantage; coal, coke, wood, and the lignites have already been used successfully, and the use of dried peat is now commanding the attention of gas engineers where this material is available. The producer gas process closely resembles the water gas process above described. It differs, however, in that the process is generally a continuous one, the steam and air blasts being introduced simultaneously. In power work the presence of considerable quantities of inert constituents has no detrimental effect upon the operation of gas engines other than occasioning the special designing of ports and passages to accommodate the larger quantities of gas than would be necessary were a richer gas used. The presence of these inert constituents in illuminating gas would obviously be out of the question.

EFFICIENCY OF PRODUCTION

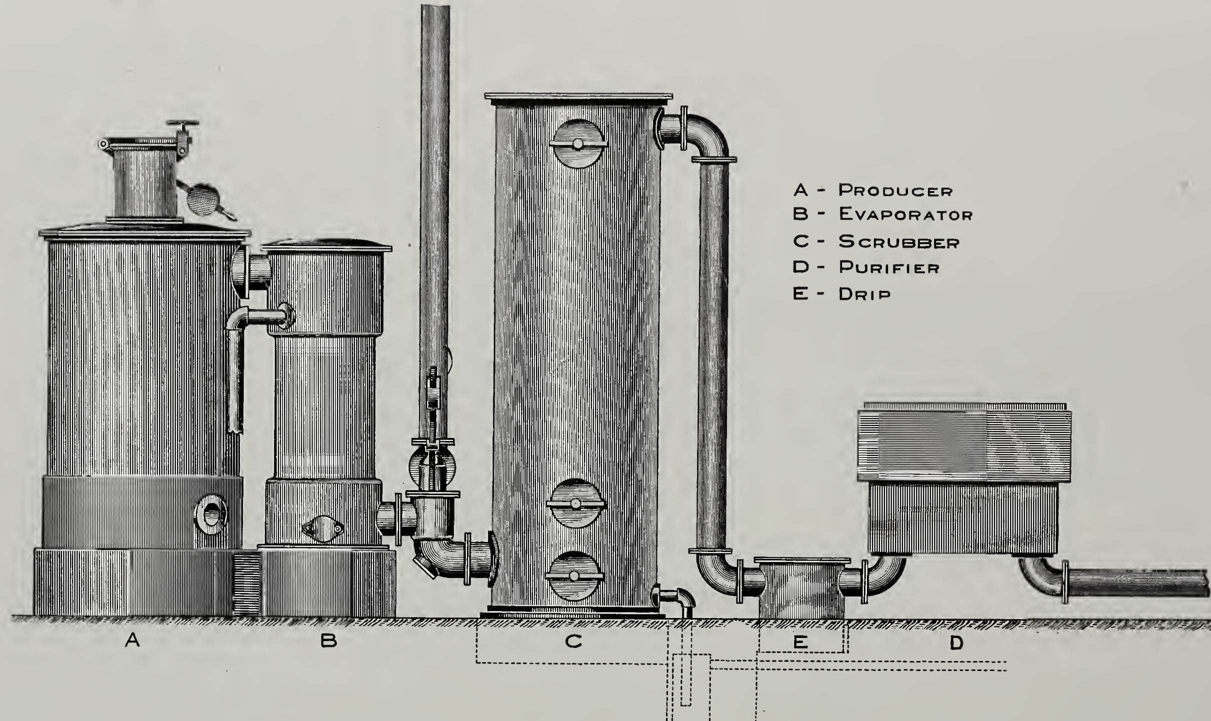
It is instructive to compare the efficiencies of the various processes described above for generating power gas, as only in this manner may an unprejudiced opinion be formed of their respective merits. Numerous definitions have been advanced for the efficiency of the process, which, although differing slightly in application, are based upon the ratio of net heat output divided by gross heat input; that is,—

$$\frac{\text{Calorific value of gas} \times \text{gas yield per pound of fuel}}{\text{Calorific value of fuel used.}}$$

In the manufacture of illuminating gas it is not a difficult matter to obtain accurately the data necessary for estimating the efficiency, but in producer gas work the volumes handled are usually so great as to prevent the employment of measuring apparatus. Some data are, however, available from experimental sources from which reasonably accurate conclusions may be drawn.

Coal gas yields the lowest efficiency, —barely 25 per cent. when the gas alone is considered; by adding the heat value of the by-product coke, however, the efficiency approaches 60 per cent. Water gas processes show an efficiency ranging from 60 to 75 per cent., depending upon the method of blowing. Producer gas processes vary considerably in efficiency, the range being somewhat higher than for water gas, namely, 70 to 85 per cent., depending largely upon the design of the producer in completing the gasification of heavy hydrocarbon distillates.

In all of these efficiencies the sensible



PRODUCER GAS POWER PLANT—SUCTION TYPE FOR ANTHRACITE OR CARBONISED FUELS. MADE BY MESSRS. R. D. WOOD & CO., PHILADELPHIA. IN STARTING, THE AIR SUPPLY MUST BE FURNISHED BY A HAND OR POWER FAN, THE WASTE GAS PASSING OUT THROUGH THE WASTE PIPE BETWEEN THE EVAPORATOR *B* AND SCRUBBER *C*. AS SOON AS GOOD GAS APPEARS AT THE TEST COCK AT THAT POINT, THE WASTE PIPE VALVE IS CLOSED AND THE GAS ENTERS THE SCRUBBER AND PURIFIER. THE ENGINE MAY THEN BE STARTED AND THE FAN STOPPED AND GAS GENERATION THEN PROCEEDS BY THE SUCTION CAUSED BY THE ENGINE

heat of the gas leaving the producer is not charged against the process, but only the gas delivered at normal pressures and temperatures. Could this sensible heat be conveniently utilised, the efficiency of the process might be largely increased.

Even upon the above basis, however, it is evident that the corresponding thermal efficiencies of a well-designed steam boiler equipment have been equaled and even exceeded by the producer gas process. Bryan Donkin, in his "Heat Efficiency of Steam Boilers," gives the results of a test on various types of steam boilers, including marine, Lancashire, Cornish, and water-tube types. Out of 273 tests the efficiency ranged from 61.2 to 69 per cent., averaging about 65 per cent. This is doubtless somewhat lower than obtainable in the best modern types, but, no doubt, represents the rule if not the exception.

THE IDEAL GAS PRODUCER

Let us glance for a moment at the essential features of a good gas producer:—

1.—A continuous gasification process, capable of wide variations in output without serious variations in quality of gas, is prescribed by the variable loads encountered in general power service, particularly in electric railway service. It is obvious that a holder might be relied upon to insure uniform gas as well as reserve capacity, but it should preferably be dispensed with.

In practice, the producer is found to accommodate a considerable range of output, due to the great heat storage capacity of the bed of fuel and the comparatively great length of time required to complete gasification. In this respect it is far superior to the steam boiler in meeting sudden demands. The latent heat of steam does not have to be reckoned with, and the chemical reactions adjust themselves to the demand for gas to a nicety.

It thus occurs that a producer may be shut off completely if necessary and started again under full capacity without a change in the quality of gas perceptible at the engine. With the fuel bed in good condition, it may readily be shut down over night or for even longer periods and still retain sufficient internal heat to be quickly blasted to its normal condition when again required.

2.—The fuel bed should be of considerable depth to insure uniform gas and complete gasification. A definite relation has been found to exist between the depth of fuel bed and the time required for gasification. A high blast velocity necessitates a deeper bed, and *vice versa*. A deep fuel bed also prevents a formation of channels of least resistance to the blast, which would result in localised high temperature and higher percentage of CO_2 in the gas.

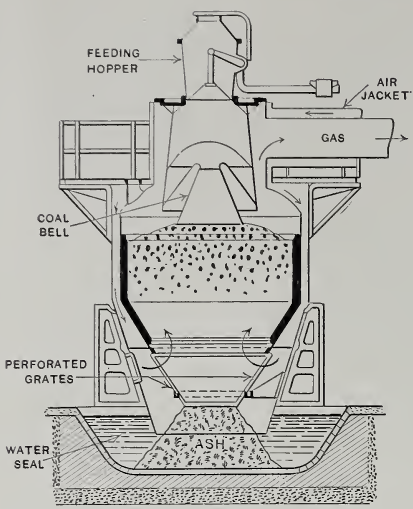
3.—Means should be provided for continuously agitating the fuel bed, to prevent packing of fuel and thus lower the resistance to the blast, which would otherwise occur; also to prevent irregular working of the producer. This has usually been accomplished by pokers manipulated through openings in the walls of the producer, or by mechanical pokers operated by outside power. The former are inconvenient, and the latter must be water-cooled. They also consume enough power to form an appreciable percentage of the total power generated by the gas. With low-grade bituminous coal, it is particularly difficult to maintain a loose fuel bed, on account of its tendency to become soft and pasty under high temperatures.

4.—An approximately continuous fuel feed is needed to preserve uniform depth of fuel bed and eliminate the results of careless, intermittent feeding.

5.—There should be an ash bed of sufficient depth to prevent loss of good fuel and of internal heat. In producers employing grate bars and thin ash beds it is impossible to prevent fuel waste from this source.

6.—Means should be provided for the removal of ashes in such a manner that the fuel bed will not be disturbed.

7.—Air and steam blasts should be introduced in such a manner as to secure uniform distribution below the fuel bed without encountering serious resistance or without diverting the zone of highest



SECTION OF MOND PRODUCER. MADE BY THE POWER GAS CORPORATION, LTD., LONDON, AND BY R. D. WOOD & CO., PHILADELPHIA. CONTINUOUS TYPE, INCLINED GRATES, WATER SEAL, AIR JACKET

temperature to the walls of the producer, which would tend to produce clinkers and shorten the life of the producer lining.

TYPES OF PRODUCERS

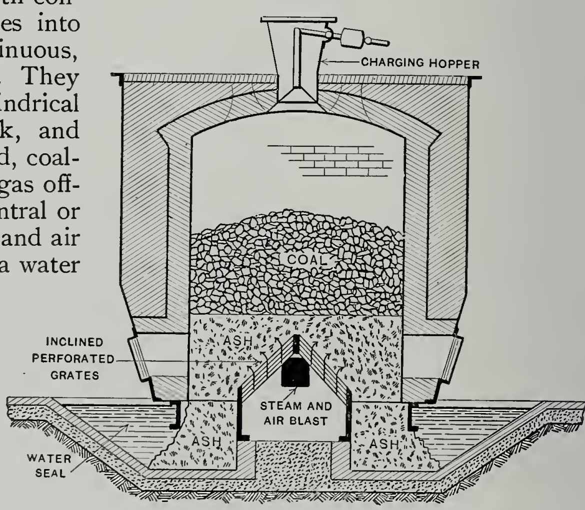
The numberless forms and modifications of the original Siemens producer that have been exploited on both continents have resolved themselves into three general classes:—(1) Continuous, (2) Intermittent, (3) Re-entrant. They all consist essentially of a cylindrical steel shell, lined with fire-brick, and provided with a double, sealed, coal-receiving hopper at the top, a gas off-take at the top or bottom, a central or transverse tuyere for the steam and air blast, and a revolving bottom or a water seal for removing ashes while the producer is under pressure or suction.

The elementary Siemens producer employed grates for supporting the fuel bed. These have been superseded by the more convenient arrangement known as the "water seal." The lower rim of the producer is water sealed in a concrete or steel-lined pit or tank, the ash bed itself forming the fuel support by piling up in pyramidal form. Ashes may thus be removed from the bottom from time to time without opening the producer.

A modification of the original grate is still, however, employed to good advantage in the Taylor producer, which is provided with a revolving bottom, rotated from time to time by gears and a hand wheel, in order to lower the ash bed to the proper point.

In the Siemens producer the air and steam blast was introduced beneath the grates, and was obliged to force its way through the ash bed. This arrangement is replaced in the Dowson, Taylor and other producers by a central tuyere passing through the ash bed to a point near the heated zone where the blast is distributed by a deflecting cap, thus permitting a deep ash bed, which, as has been pointed out before, is highly desirable.

A distinctive form of tuyere is used in the Duff producer. It consists of an inverted "V"-shaped box or "doghouse" extending entirely across the producer, thus securing a wider distribution of the steam-air blast, with lower velocity and lessened resistance. A still further modification of the in-



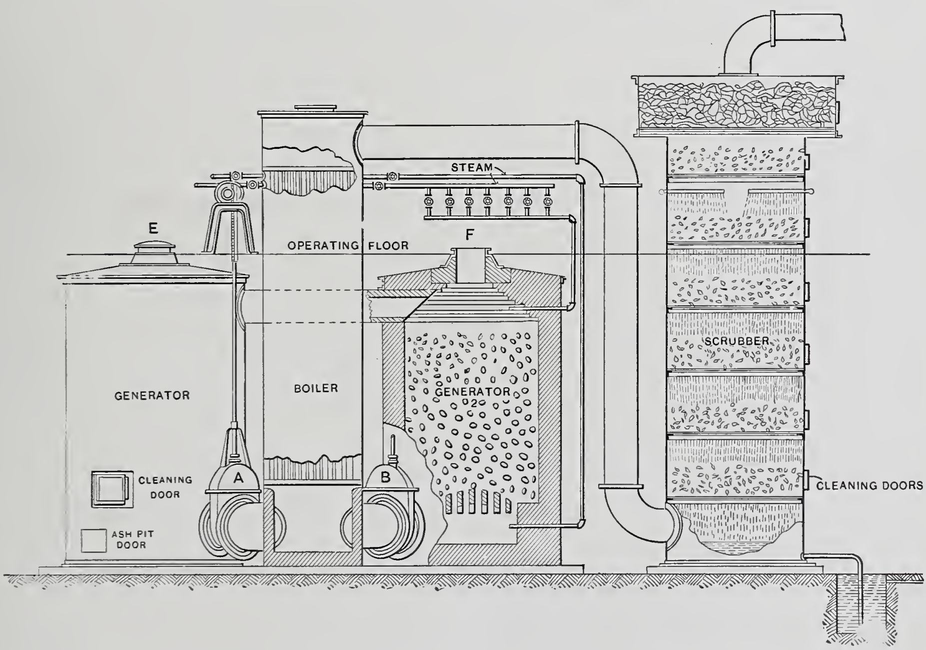
THE DUFF PRODUCER. MADE BY W. F. MASON, LTD., MANCHESTER, ENGLAND. CONTINUOUS TYPE. TRANSVERSE TUYERE

clined tuyere is found in the Mond producer, in which the lower walls of the producer are partially contracted toward the centre to form an inverted cone, through perforations in which the air and steam blast is introduced.

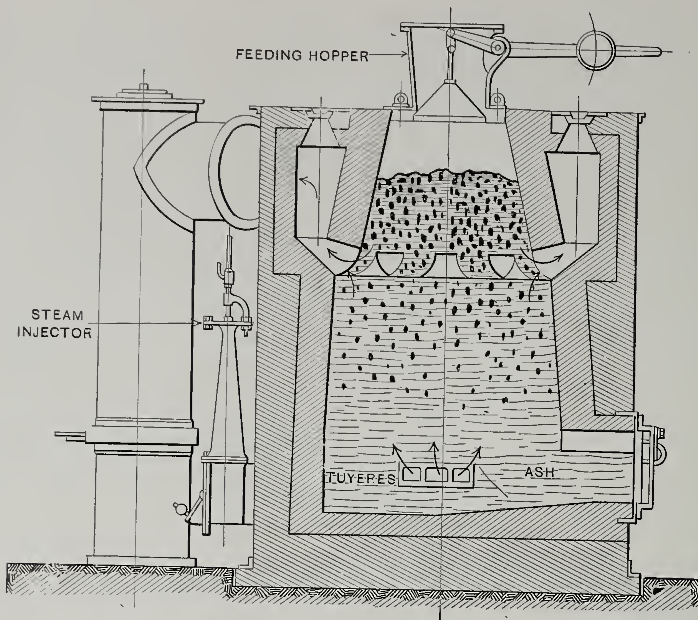
In all of the above-mentioned forms the fuel bed is agitated from time to time, to prevent packing, by pokers manipulated through poke holes in the roof or walls. One American producer, the Frazier-Talbot, employs a water-cooled poker revolving about a vertical axis in the centre of the producer. It is operated continuously by some form of motor, or, in the case of a battery of producers, by a line shaft and worm gear.

All of the above forms of producers are of the upward flow, "continuous" type, and operate successfully on anthracite or semi-bituminous coals with the proper scrubbing appliances.

In dealing with bituminous coals, the "re-entrant" principle has been adopted, with the object of gasifying the tar vapours within the producer. It has been clearly embodied in two forms. In the Wilson, an English producer, the gas is not removed at the top, but from openings at the bottom of an inverted brick hopper nearly half way down the walls. It is claimed by the inventor that the green coal in the upper part of the producer undergoes distillation to the coke stage, and the liberated tar vapours, forced to descend through the hot fuel bed to reach the outlets, are largely broken up into fixed gases. That this is, however, only a partial remedy, is evident from the statement in the inventor's own report:—



LONGITUDINAL SECTION OF A LOOMIS-PETTIBONE GAS PRODUCER INSTALLED BY THE POWER & MINING MACHINERY CO., NEW YORK. THE STEAM RAISED IN THE BOILER IS USED INTERMITTENTLY TO MAKE WATER-GAS. FOR THIS PURPOSE THE FEED-DOORS E AND F ARE CLOSED, AND ALSO THE VALVE B. STEAM IS THEN ADMITTED UNDER THE GRATE OF PRODUCER NO. 2, AND IS DISSOCIATED AT THE TEMPERATURE OF THE FIRE, FORMING WATER-GAS IN ITS PASSAGE UP THROUGH PRODUCER NO. 2, ACROSS THE TOP CONNECTING-PIPE TO PRODUCER NO. 1, DOWN THROUGH THE LATTER, AND OUT BY VALVE A TO THE BOILER, THE SCRUBBER AND THE GAS-HOLDER. THE NEXT TIME WATER-GAS IS MADE THE DIRECTION IS REVERSED; THE VALVE A IS CLOSED, AND THE GAS-RUN IS MADE UP THROUGH PRODUCER NO. 1 AND DOWN THROUGH NO. 2. OR, WHEN HALF THE RUN IS MADE UP PRODUCER NO. 1, STEAM MAY BE SHUT OFF WHILE VALVES A AND B ARE REVERSED, AND THE OTHER HALF OF THE RUN MADE UP PRODUCER NO. 2



THE WILSON PRODUCER. MADE BY THE HORSEHAY CO., LTD., HORSEHAY, ENGLAND.
RE-ENTRANT TYPE. TUYERES IN SIDE WALLS

"The fuel, for choice, is any description of free-burning rough slack. If it has slight caking qualities, it is not detrimental; but if it is of a strongly coking nature, it is not suitable for use in a gas producer."

Practically the same arrangement forms an important feature of the French Lencauchez producer. The inventor of this, in addition, mounted a small boiler upon the top of his producer in order to reclaim some of the sensible heat of the escaping gases, thus providing, without extra expense, the necessary steam for blowing his producer. It is also claimed that in the Mond producer, by the use of an especially long fuel feeding bell, extending down into the producer, the green fuel therein undergoes distillation, resulting in the removal of the tar vapours by forcing them down through the hot fuel bed. In this regard this producer is evidently subject to the same limitations as the two other representatives of the re-entrant type above described.

A recent utterance upon this subject by Mr. J. Emerson Dowson is interesting here:—

"For several years I have been trying various methods of making good, clean gas on a practical scale with bituminous coal; but I have only recently satisfied myself that the results were good enough, on the lines I thought it right to follow. I consider it wrong to let the gas leave the producer highly charged with tarry vapours, and then to remove the tar by scrubbing, etc., as it not only leads to waste of some of the most valuable heat-giving constituents of the coal, but it adds materially to the size and cost of the scrubbing plant and the difficulty of obtaining clean gas."

He does not state his method of accomplishing the result, but intimates that the "re-entrant" principle is involved.

Of the "intermittent" type, we find a prominent representative in the Loomis-Pettibone producer. Two generators are employed, connected in series at the top and provided with independent outlets at the bottom. The process is identical with that of water-gas making, except that blast gas is saved, being delivered to a separate holder and finally mixed with the gas

from the water gas holder in the desired proportions for use in gas engines. The process of gas making is reversed ten or twelve times per hour, so as to maintain the producers at the proper temperature.

The essential feature in the arrangement is that, with bituminous coals, the tar vapours liberated from the green fuel in the first generator are forced to pass down through the hot fuel bed of the second generator, where they are, of necessity, converted into fixed gases. A separately driven exhauster is employed to overcome the necessarily high resistance of the two fuel and ash beds.

This form of producer stands at present alone in its ability to gasify bituminous coals, and it has consequently met with considerable success. It has the advantage, too, that by separating the gases as generated, heating and metallurgical operations may be carried on with the water gas, which is of high flame temperature, while the blast gas may be reserved for power purposes, or a mixture of the two may be employed. A practical application of this may be found in the plant of the Winchester Repeating Arms Company, at New Haven, Conn., U. S. A., where power for lighting their factory and operating machinery is supplied from a gas engine plant using gas from the producer. The brass melting furnaces, heating ovens, etc., are similarly supplied from the water gas holder.

A recent development is known as the "suction" system, having for its object the generation of gas at the precise rate demanded by the load upon the engine. For this purpose the engine is arranged to furnish the required suction at the producer upon its inspiration stroke. Holders may, therefore, be dispensed with, although at a risk of non-uniform gas. The system is advocated by Koerting, Duff, Otto, and others, but may as well be applied to any well-designed producer. It is attractive in its apparent simplicity, but involves difficulties not encountered in the pressure system. (See page 534.)

Ammonia recovery systems, of which the Mond is representative, are finding considerable favour, especially in Great Britain where a corporation is now erecting a large central station of forty million cubic feet daily capacity for distributing Mond gas to numerous towns throughout the South Staffordshire district, covering 123 square miles. It is contemplated to eventually construct five central stations of like character within this district to complete the system.

This undertaking establishes an instructive precedent in gas production, likened only to the enormous American natural gas distributing systems of Western Pennsylvania, Ohio, and West Virginia. It is the ideal field for recovery systems, which, successful upon such a gigantic scale, might prove distinctly unsuccessful in small power installations of a few thousand horse-power.

In the United States a large Mond system is in operation at the works of the Solvay Process Company, Detroit, Mich. Briefly, the essential feature of the Mond process is the maintenance of such a low temperature as to prevent the destruction of the ammonia, which passes over with the gas and is subsequently reclaimed in the form of ammonium sulphate to the extent of 20 to 40 per cent. of the original weight of the fuel gasified.

Thus, with $(NH_4)_2\ SO_4$ at $60 per ton and slack at $1, the advantage from the sale of ammonia is obvious. The low temperature in the producer is obtained by using large quantities of steam,—as high as 2½ pounds of steam per pound of coal,—in the blast. Thus, the gas contains considerably more hydrogen than ordinary producer gas, not sufficient, however, to occasion trouble in gas engine work.

The consumption of coal during "stand-by" periods is very small in a good producer plant. Mr. Emerson Dowson, in a recent paper, has by actual test shown it to be from 2 to 4 pounds (3 pounds average) of coal per hour in plants averaging 250 H. P. Comparative observations made by him on eight steam plants of about equal capacity showed an average "stand-by" coal

TABLE II.—COST OF OPERATION—MANUFACTURED GAS

Plant No.	Character of Load	Kind of Gas	Per Cent. of Total Gas Generated, Used for Engines	Cost Charged to Engines. Cents per 1,000 Cubic Feet	Gas per KW-hour at Switchboard ft.	Cost per KW-hour. Gas Only. Cents	Rated Capacity Full Load. b.h p.	Remarks
1	Railway	Mixed	54	37.57	43.75	1.65	685	Average 6 months
					28.40	1 07		All-day run
				at 18	46.57	0 84		Gas at cost
2	Arc	Coal	----	18	33.64	0.61	170	Average 4½ months
3	Arc and incan.	Mixed	37.5	34.6	----	---	320	Output not metered
4	Incan.	Coal	26	39.8	48.4	1.93	360	Average 9 months, 1902
5	"	Coal	5	33	28.5	0.94	280	Night run 65% rating
6	"	Mixed	19.5	29.5	41 7	1.22	140	Average 6 months, 1902
7	"	Coal	15.0	20	41.0	0 98	85	Average 19 days Aug., '02
8	Incan. and arc	Natural	100	15.0	12 4	0 18	803	Special test
				16.0	21.5	0.34		Average 6 months
	Average	----	----	33.9	39.0	1.4	---	

Average cost per KW-hour at 20c. gas (excluding No. 11) 0.828
Average cu. ft. gas per KW-hour 39.0

consumption of from 35 to 180 pounds per hour (averaging 70 pounds).

In this brief glance at the present status of producer practice it has been possible only to touch upon the main features of representative forms. It is an interesting reflection that, in spite of this array of different forms and modifications, excellent in themselves for specific purposes, the fact, nevertheless, remains that the one all-important problem has yet to be satisfactorily solved, namely, the complete conversion into fixed gases of all the combustible constituents of bituminous coal; this, by a continuous process, in a single producer capable of being operated for an indefinite length of time.

RESULTS OBTAINED WITH GASEOUS FUEL

It may be appropriate, in closing, to present results of some tests and observations of different authorities concerning the operation of gas engines on gas fuel. In general, whatever the nature of gas used, an engine of proper design and construction will consume from 10,000 to 12,000 British thermal units per brake horse-power-hour at or near full load. At light load, the heat consumption will increase, owing to the fact that the mechanical losses remain practically constant at all loads, and, therefore, form a relatively greater proportion of the work done by the engine at light loads. With natural gas of approxi-

TABLE III.—COST OF OPERATING GAS PLANTS*

	Plant: Midland Railway Co., Leicester	Urban District Station, Walthamstow	Birmingham Small Arms Co., Smallheath
Engine:			
Capacity tested	300	1,500	250
Number	6	7	1
Make	Crossley	Westinghouse	Westinghouse
Length of run	5 months	12 months	5 days
Load factor	------	15.23	----
KW-hour generated	200,497	659,796	6,339
Remarks—service	Arc and incandescent lighting, Dowson gas	Arc and incandescent lighting, Dowson gas	Electric light and power, Dowson gas, 166 Eff. B. t. u.
Duty, plant:†			
Lbs. per KW-hour	3	2	1.93
Lbs. per E.H.P	2.25	1.5	1.44
Cost:			
Coal per ton	$3.75	$6.50	$5 00
Fuel per KW-hour	.123c.	.17c.	----
Oil, waste, water	.020c.	.095c.	----
Wages	.292c.	.165c.	----
Repairs, maintenance	.039c.	.015c.	----
Total cost power, cents per KW-hour	.473c.	.445c.	----
Authority	R. M. Deely, Supt. Locomotives	F A. Wilkinson, Elec. Engr. in charge	Henry Lea, Consulting Engineer

* J. E. Dowson, Journal Institute Electrical Engineers, April, 1904. † Including "stand-by" losses.

mately 1000 total British thermal units per cubic foot calorific value, the gas consumption averages about 10 cubic feet per B. H. P. per hour.

As the calorific value decreases, the gas consumption proportionately increases. Thus, with coal gas of about 350 British thermal units heat value the consumption of gas may be 30 cubic feet per B. H. P. hour. With producer gas of 125 British thermal units heat value the consumption may be 80 cubic feet per B. H. P. hour.

The curves on the next page show the performance of a high-grade engine on natural gas of 1000 British thermal units calorific value:—

Table II. gives the results of a number of power plants utilising manufactured gas from the holders of illuminating gas companies. The results embrace regular operating conditions, whether favourable or unfavourable, in the attainment of high engine economy.

As in the case of steam power plants, the result of greatest interest is the duty of the producer gas plant expressed in pounds of coal per horse-power-hour delivered by the engine. Unfortunately, the majority of complete producer plant tests now on record have been of such short duration to arouse some suspicion as to the correctness of the fuel consumption.

In boiler testing, a ten-hour run is usually considered to be the minimum, and twenty-four hours are a common length of run. It even then becomes necessary to enter corrections for differences in water level and conditions of fuel bed between that at the beginning and the ending of the test.

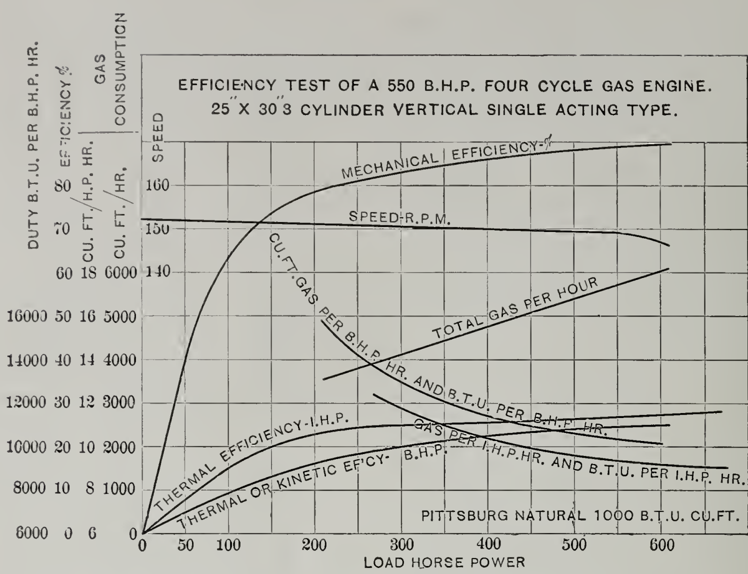
In gas generators, the necessity for long runs is even greater, owing to the greater "time constant" of the process; that is, the time required for a unit weight of fuel to be completely gasified. It is, therefore, hardly possible to meet these conditions in short tests of one to two hours' duration, except possibly when the observations are made during a long, continuous run.

In Tables III. and IV. a number of tests have been collected from various authoritative sources. When available,

TABLE IV.—TESTS OF GAS POWER PLANTS*

Engine	Rated H. P.	Load H. P.	Duration of Test	Producer	Fuel Used	Fuel, Lbs. per H. P. Hour	Cu. Ft. Gas per H. P. Hour	Calorific Value of Gas	Service	Authority	Remarks
Premier	500	342.4 E	5 hrs.	Mond	Anthracite	1.04 E	74.42 E	*e* 143.8	⅔ load, driving generator	Humphrey	
Crossley	....	117.4 B	......	"	"	1.26 B	79.3 B	*t* 155	Driving generator	"	Cal. val. coal, 12,060 B.t.u.
"	400	334.4 E	6 hrs.	"	Anth. slack	1.14 E	81.22 E	*e* 142.5	Electrical load	"	
Deutz	....	*c* 151 B	......	Deutz	Gas coke	1.60 B	......	......	Driving water-works pumps	Meyer	Cal. val. coke, 12,963 B.t.u.
Simplex	....	*c* 220 B	......	Lencauchez	Anzin coal	1.03 B	85 B	*t* 152	Driving flour mill	Delamare & Deboutteville	
Crossley	....	*c* 57.6 B	......	Dowson	Anthracite	1.36 B	90 B	*e* 144	Driving generator	Meyer	Cal. val. coal, 14,200 B.t.u.
"	....	105.6 E	*x* 2½ hrs.	Mond	Anth. slack	*a* 1.23 E	88.1 E	......	Electrical load	Humphrey	*x* Out of a six-hour run
Stockport	80	64.4 B	36 hrs.	Dowson	Anthracite	*b* 1.37 E	......	......	Electric lighting	Handock & Dykes	
Crossley	140-70	180.3 I	8 hrs.	"	"	0.95 I	......	......	Rope machinery	Engr. Vulcan Insur. Office	
Premier	(2) 60	*d* 101 B	5 hrs.	"	"	1.18 B	......	......	Electric lighting	Prof. H. Robinson	
"	(4) 60	*d* 134 B		"	"	1.25 B	......	......	Electric lighting	"	
Stockport	40	40 B	12 hrs.	"	"	1.16 B	......	......	Flour mill	Arnold & Sons	
"	70	73 I	55 hrs.	"	"	0.89 I	......	......	Weaving	Andrew & Co.	
Crossley	150	118.7 I	8 hrs.	"	"	.755 I	......	......	Flour mill	Dowson	
Simplex	76	76.8 B	23½ hrs.	"	"	1.35 B	......	......	Brake test	Prof. Witz, 1890	
Crossley	....	*c* 41.1 B	......	"	"	1.47 B	88 E	*e* 144	Driving generator, under-load	Meyer	Cal. val. coal, 14,200 B.T.U.

* Journal I. M. E., February, 1901.
I = I. H. P.
B = B. H. P.
E = E. H. P.
a = Estimated from average gas yield.
b = Includes "stand-by" losses.
c = Metric H. P. = 1.014 English H. P.
d = Estimated from E. H. P.
e = Effective or "lower" heat value of gas.
t = Total or "higher" heat value of gas.



THE PERFORMANCE OF A HIGH GRADE ENGINE ON NATURAL GAS OF 1000 B. T. U. CALORIFIC VALUE

the length of run is given. The tests range in date from 1895 up to the present time; but in the case of the older tests, as both engines and producers at the time were quite well developed, the results may be regarded as fairly indicative of modern practice.

From the results in these tables, it appears that a well-equipped gas power electric generating plant should show a duty of at least one pound of coal per indicated horse-power-hour; many installations have shown much better under test, notably that at Winnington, which has been subjected to careful tests by Mr. H. H. Humphrey. The results from the three plants given by Mr. Dowson also indicate what economy may be obtained from comparatively small engines under ordinary conditions of operation. It is doubtful if any steam plant, laid out and equipped as simply as those in question, has shown as high economy as that at Walthamstow, and the period of time covered by the test leaves nothing to be desired in the way of accuracy, outside of customary instrumental errors.

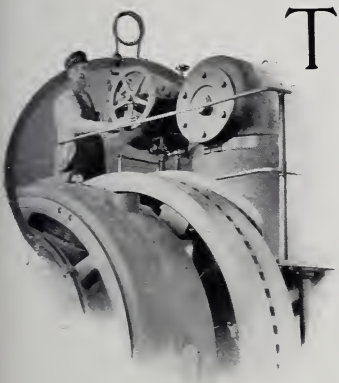
Considered collectively, the data at present available on the operation of gas power plants prove conclusively that even in small powers an opportunity is afforded for instituting important economies in the generation and use of the power over that prevailing at the present time.

There is in this an opportunity that commands the attention of power users; and even though the use of steam power be fostered in every possible way by its advocates, the systems which will reduce operating expenses to the greatest possible degree will find ultimate and universal adoption.

CONDENSING PLANT

TYPES OF BRITISH CONDENSERS AND ACCESSORIES

By W. H. Booth



THE demands of the steam turbine have brought the subject of condensers into more than usual prominence. In the old factory practice, unless a factory was compelled to draw its supply of condensing water from a hot canal or a mill pond, it was usual to attempt to secure 13½ pounds of vacuum or from 27 to 27½ inches of mercury. Jet condensers were practically universal, and the only cooling arrangement was the radiation and evaporative loss from the exposed surface of the large condensing pond. In exceptional cases, even with a pond only, a vacuum of 14 to 14¼ pounds has been obtained; but this could be done only where all glands were carefully packed and where particular attention was paid to the making of all joints in the exhaust pipe, and by the liberal and constant use of the paint brush to keep hermetically sealed all surfaces on the other side of which was a pressure below atmospheric pressure.

It has been reserved for modern engineers to gaze with complacency on the vacuum gauge showing only 15, 20 or 22 inches with a cold water supply, while 26 inches were looked upon as the maximum of excellence. The cry was all for high-pressure steam and its advantages, which, after all, are to be secured only by equally high-pressure attendance. The vacuum was neglected, as though it were a matter of no moment, and it was forgotten that, having gone to the expense of condensing plant, an extra 5 or 10 inches usually cost nothing to obtain except proper attention to air-tightness. High-pressure steam demanded metallic packings, because of its high temperature; but there is no high temperature about the low-pressure rods and valve spindles, and these still require to be packed with soft and fibrous packings so that air may not enter.

The following few figures will serve to show a few facts connected with condensing problems. It will be observed

I.—Inches of Vacuum	II.—Absolute Pressure	III.—Temperature F.°
0	14.697	212.00
25½	2.172	129.31
26	1.926	124 89
26½	1.680	119.94
27	1.435	114.34
27½	1.189	107 84
28	0 944	100.05
28½	0.698	90.24
29	0.453	76.80
29½	0-207	54.21

that as the "vacuum" increases towards perfection each half inch represents 0.246 pound pressure; but, as the pressure falls, the ratio of each pressure to the next half inch less is every time larger.

Now the volume of a gas varies inversely as the pressure. At 29½ inches vacuum, or 0.207 pound pressure, the volume of air or vapour in the condenser is about 70 times what it is at atmospheric pressure. At 27½ inches it is not even 13 times normal volume. In pumping air at these low pressures, to maintain a vacuum of 29½ inches against a given inleak of air would demand a pump nearly six times the size of what would maintain a 27½-inch vacuum. Obviously, therefore, the maintenance of high vacua demands either huge air pumps or small air leak-

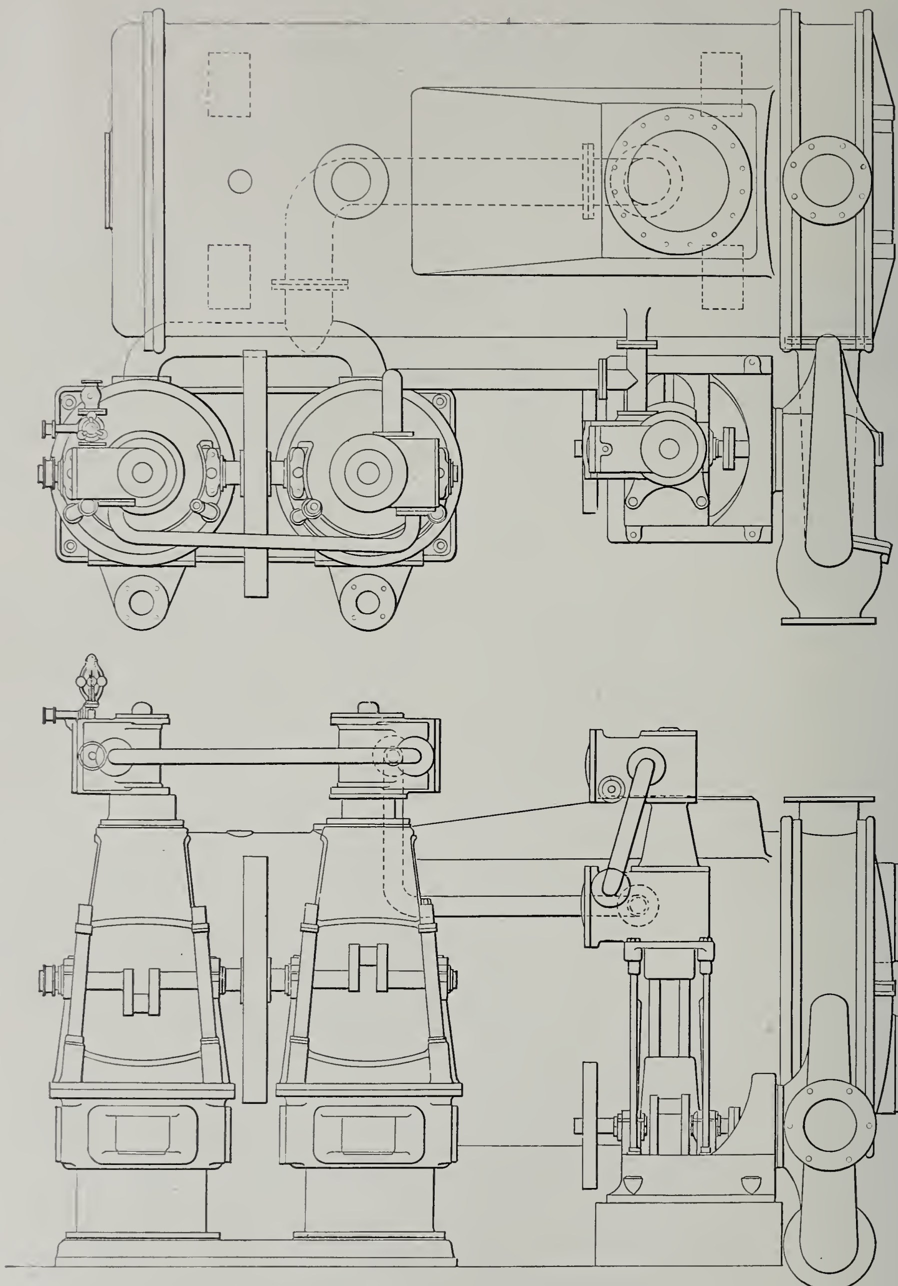


FIG. I.—CONDENSING PLANT MADE BY THE MIRRLEES WATSON COMPANY, LTD., GLASGOW

age. The former will soon increase the capital and working costs to an extent sufficient to swamp the benefit of the higher vacuum. The latter may be secured by the exercise of that care for which the engineer in charge is supposed to be paid, and the expense of a good packing or of a little paint or filled varnish. It is against leakage only that precautions are much needed in a modern plant, for the feed-water, drawn from a surface condenser, is purged of air by repeated boiling.

Leakage is one reason why the feed supply should fall towards the feed pump, and it is an argument against electrically-driven feed pumps, for, usually, these are so made that they cannot be nicely regulated to fit the feed required; generally they run too fast and are throttled in their suction and draw air at glands, which goes forward with the feed and expands immensely in the condenser. Air ought, of course, to be trapped out of the feed system at some point beyond the economiser, or before it, if too high a temperature is reached beyond it. An upstanding air vessel with a long, slotted opening to the feed pipe would effect the trapping, and a float-actuated "snifting" valve would let it out.

No matter how small the volume of air to be dealt with, no vacuum can be better than that proper to the temperature of the water. Any further improvement would instantly be nullified by the evaporation of the water.

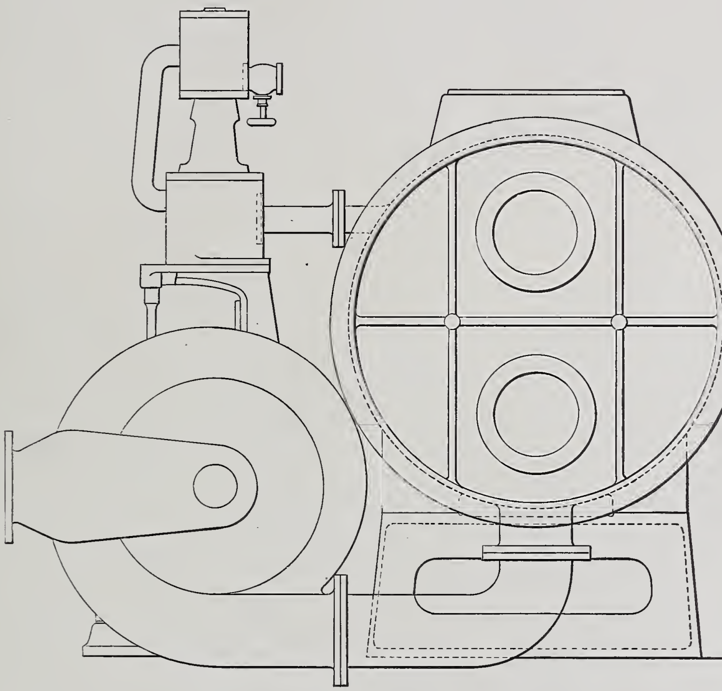


FIG. 2.—AN END VIEW OF THE PLANT OPPOSITE

In Column III. of the figures on page 543 the temperature proper to any vacuum above 25 inches may be found. The very high vacuum of 29½ inches would demand a temperature of 54.21° F. Such a vacuum would, of course, be obtainable under special conditions. With circulating water drawn from a running stream during a severe winter, the temperature of the water would be, say, 33° F., and it would be possible to add 21° to this. Each pound of steam

to be condensed loses $1178 - 54 = 1124$ British thermal units. Then $1124 \div 21$ = say 54 pounds of circulating water per pound of steam. With a really efficient counter-current condenser the steam may fall to 54° F., and the circulating water may become somewhat hotter. Still the difficulty is present of very large flow of water.

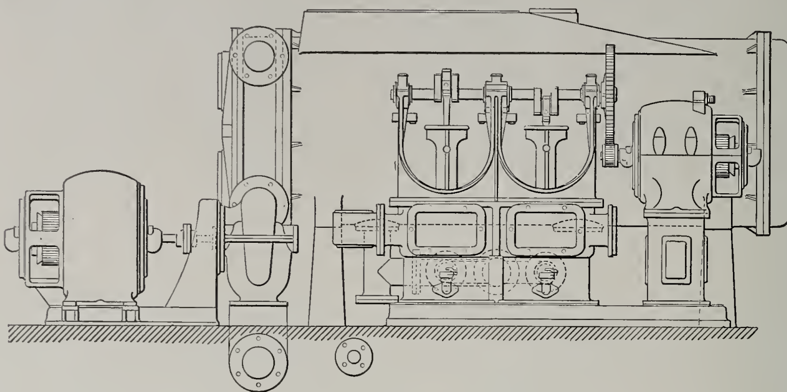


FIG. 3.—AN ELECTRICALLY DRIVEN CONDENSER OUTFIT MADE BY THE MIRRLEES WATSON COMPANY, LTD.

Allow the vacuum to drop to 29 inches, and at once the steam loses only $1178 - 76$, or, say, 1100 British thermal units; but the water may now gain $76 - 33$ = say, 43°, whence $1100 \div 43$ = say, 26 pounds of circulating water. Ordinarily we should do well to secure water even as cool as 60° and to reject it at 100°, so gaining 40° while depriving each pound of steam of $1178 - 100 = 1078$ British thermal units, so that the relative volumes are now 28 to 1 and the vacuum 28 inches, which is as good as can be expected under what may be called first-class conditions.

At this temperature and vacuum the air present in the condenser has a volume relative to its normal volume of $14.7 \div 0.944$ = say, 16, including expansion by temperature. If, by means of the supplementary steam jet, a differential pressure of only a pound can be worked up, or, say, 2 inches of vacuum, the air pump will be asked only to take in air at $14.7 \div 1.926$ = say, 8 times normal volume, thus doubling its efficiency. The table of figures on page 543 contains everything necessary for the estimation of what can be effected under given conditions.

Where condensing water is available only at 80° F., and in such quantity that it must be allowed to rise to 120° F., it is certain that an air pump of large size will be out of place. Where there is absence of much air, it is certain that many air pumps are acting simply as boiling pumps and are abstracting vapour from hot water and effecting positively no good,—merely wasting power. It becomes correct practice, therefore, to supply smaller air pumps where there is no hope of other than warm injection or circulating water.

The independent condensing set has its advantages and its disadvantages. In the hands of a good and careful engineer, who minimises the leakages of air by attention to joints and packings, the air and circulating pumps can be run at a minimum speed consistent with the conditions. In the hands of less efficient men a drop of vacuum is made up by running the air pump faster and pouring an excessive volume of water through the condenser. There is evidently something wrong where a vacuum of 22 inches is accompanied by a discharge temperature of 90° F. Either the condenser is not efficient or there is air leakage. To know if these things are so, it is necessary that there should be thermometers on the inlet and outlet

of the circulating water and on the outlet of the condensed water, for, when these figures are consistent, it is obvious that the air to be dealt with must be in excess of the ability of the pump to take it away.

Air leakage can be discovered readily where there is an independent condenser and pump, by pumping up a vacuum with all openings closed and noting how long the vacuum is held after stopping the pump. This may be tested with and without the exhaust valves of each engine open. Air leakage will be found possible at the spindles of these valves, at the water cocks of the cylinders, at pipe joints, or at the atmospheric valve, which ought to have a water seal over it, and this should not too quickly drain away through the valve. A pumped up vacuum of 28 inches should not drop more than two inches in one hour after stopping the pump.

The action of a condenser is simply to transfer heat from the exhaust steam of an engine to a mass of water. Approximately enough for ordinary calculations, each pound of steam must part with 1100 British thermal units, and each pound of cooling water will pick up 1 British thermal unit per degree of rise of temperature. The calculation of quantities as already illustrated is, therefore, very simple.

There are two main types of condenser, those which interpose a thin sheet of metal, usually in the form of a tube between the steam and the water, and those which allow the cooling water to mix with the steam. In the latter, or jet condenser type, as it is usually termed, a stream of water is allowed to gush into the condenser, and no doubt it enters in a gyratory manner and breaks up into spray. Condensation of the steam is instantaneous,

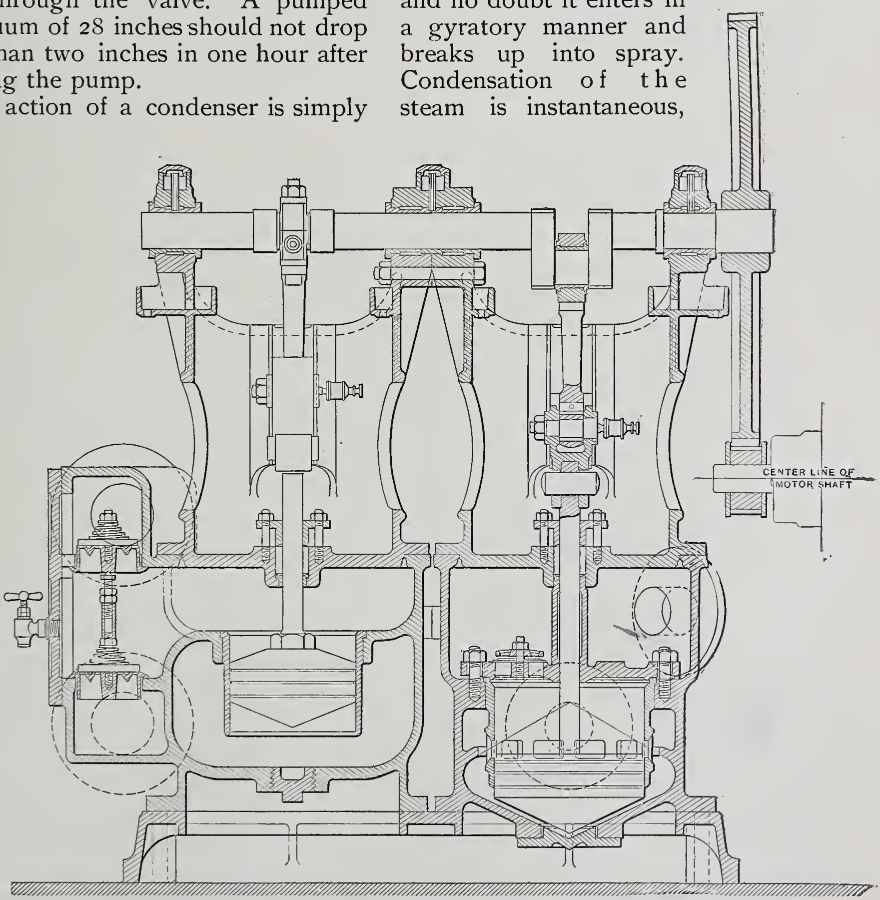


FIG. 4.—ELECTRICALLY DRIVEN AIR AND CIRCULATING PUMPS MADE BY THE MIRRLEES WATSON COMPANY, LTD.

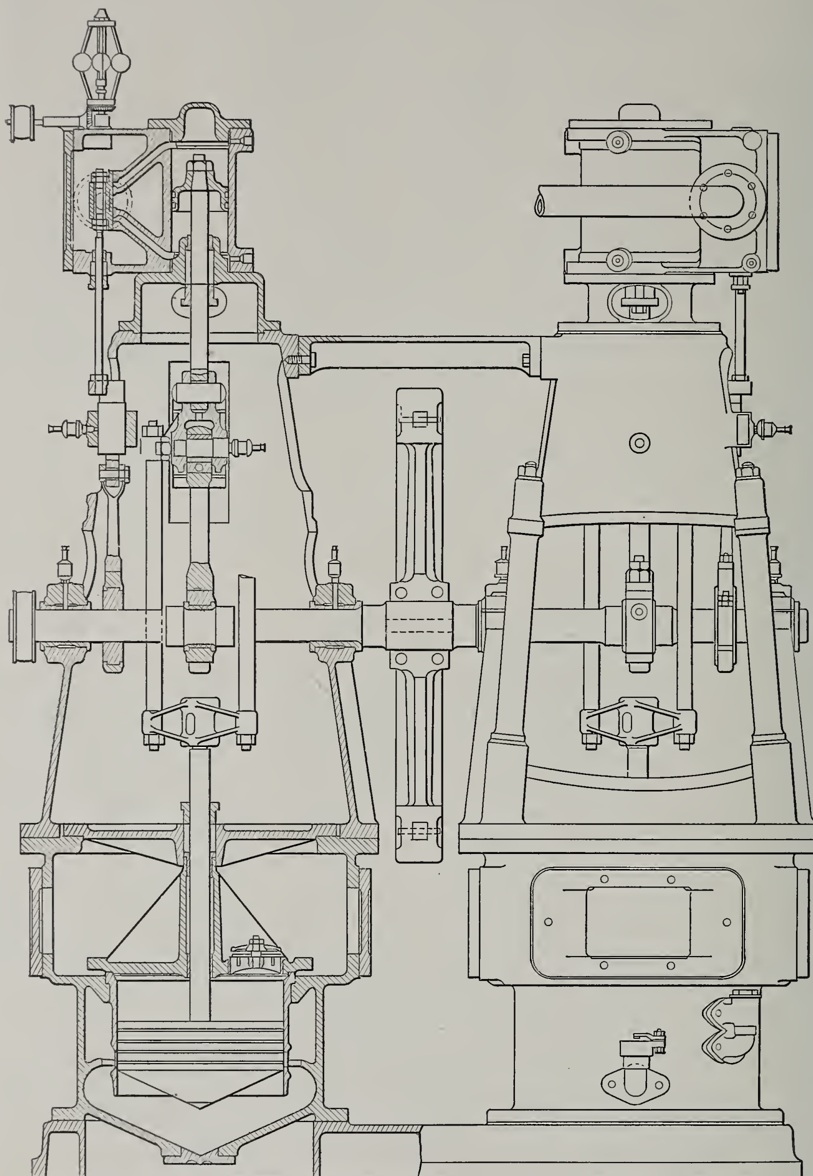


FIG. 5.—A STEAM-DRIVEN CONDENSER SET OF MIRRLEES WATSON COMPANY MAKE WITH A TWIN SET OF AIR PUMPS

and the water is drawn away by the air pump, or it may be drawn away by a separate pump, leaving the air to be dealt with by a socalled dry air pump, the air being drawn past the incoming cold water and taken hold of by the air pump at minimum bulk.

With bad feed water it is usual to employ the second type or surface condenser. This usually consists of a large number of thin brass tubes through which water is passed and over the external surface of which the steam is distributed. About 10,000 to 12,000 British thermal units per hour per square foot of surface are usually assumed to be passed through the tube surface, or say ten pounds of steam may be condensed per hour per square foot.

Care is necessary with a surface condenser that there is not too direct a path from the inlet to the air pump outlet. The flow of exhaust steam should sweep over the whole tube surface, or the corners of the condenser will become air logged and the vacuum impaired. Hence it is usual to place plates of thin metal opposite the inlet opening of a condenser for the purpose of distributing the steam towards the tube ends.

In some cases a line of tubes is left out every few rows. The tubes are omitted to a depth of several inches down into the body of the tubes. In a large condenser several such rows are left out, and the wide gaps left by the omitted tubes form an easy way for steam to get right amongst the mass. The walls of the gap afford so much more area for the exhaust steam to penetrate between the tubes than if it had to find its way entirely from the top surface through the spaces between the tubes. The gaps extend only about half way down the bundle of horizontal tubes.

Assume that in a tube bundle, 4 feet wide on the top surface, there are three gaps, each extending 18 inches into the heart of the bundle; then each gap offers 3 feet of wall surface, and the total opening for steam is 13 feet. The certainty of each tube being touched by steam is also greater, and the risk of back pressure on the piston is reduced.

There is no mystery and need be no guess-work about the proportion of water required to condense a given weight of steam. To estimate the quantity in any case it is first necessary to know from the engine maker how much steam the engine will require per I. H. P.-hour. Calling this quantity x, the next thing required is the number of degrees of temperature to be added to the feed water. This is the difference between its inlet temperature and its final temperature. The final will usually be from 100° to 110°, and the inlet temperature may be 53° if from a number of wells in gravel at a depth of, say, 40 feet, or it may be 75° if from a cooling tower. Let this rise be called y. Then the heat to be lost by the exhaust steam will never exceed 1100° units per pound, and the total units will be $1100 \times$ I. H. P. $\times x$, and the product of these three quantities, divided by y, will give the ratio of circulating water required.

The calculation is very simple, but it is often neglected, and steam users are found worrying about a supply of fifty times the feed where the circulating water is at 53° F. simply because they may have required that quantity with the supply at 80° F.

The question of water temperature is important, and cannot be too much emphasised. Engineers too often pay no attention to temperature, and appear to rely upon sheer bulk of water passed through the condenser. Temperature is everything, might almost be written. Certain it is that with a water supply at 52° F. the volume of circulating water need not be more than about twenty-five times the feed supply, for there will never be so much as 1100 British thermal units to be disposed of from each pound of feed water. The total heat above zero degrees Fahrenheit is only 1178 British thermal units, and the hot-well temperature may be 100° F., leaving only 1078 British thermal units to be carried off by the condensing water, if no allowance is made for the radiation losses. Now condensing water can often be obtained alongside a river at a temperature, as stated, of 52°, and such

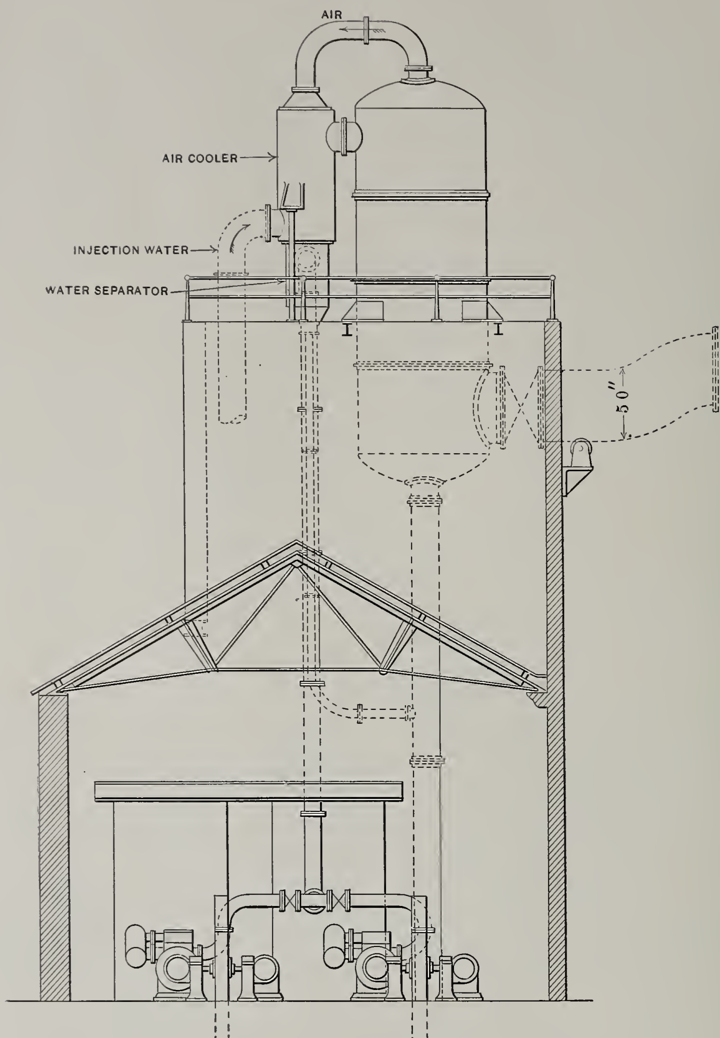


FIG. 6.—A BAROMETRIC CONDENSING PLANT

huge volumes of circulating water are not then required as they are when the water supply is from a cooling tower at 70° to 80° F.

Among the general plant for condensing outfit there are surface condensers, jet condensers, ejector condensers, barometric condensers, various types of air pumps, wet and dry, and many kinds of centrifugal pumps. These various articles can be coupled up in a great variety of combinations, and it devolves upon the engineer to select the best combination for each particular case. Quite a usual combination is that of the surface condenser, the bucket air pump, and the centrifugal pump to circulate the condensing water.

Similarly, when the water supply does not flow to an ejector condenser, the water is forced to it by a centrifugal pump. With the barometric condenser, which is very often a jet condenser, with a long tail pipe of 30 feet or so to carry off the water, the air pump has only air to deal with.

Some particulars of condensing plant manufactured by the Mirrlees Watson

Company, Ltd., of Glasgow, are given in Figs. 1 and 2, which show one of this firm's combinations of surface condensing plant with steam-driven air and circulating pumps. Fig. 3 shows a similar plant, but with the pumps arranged for electrical driving, the circulating pump in each case being of the centrifugal type and the air pump of the Edwards single-acting type. When the head against which the circulating pump works is fairly constant, either of these combinations will prove satisfactory and efficient; where the head is more variable, water pumps of the double-acting, reciprocating type are preferred, though their first cost is greater than that of the centrifugal pump.

Another arrangement which is frequently employed is the combination of air and reciprocating water pumps, as in Fig. 4, which shows a set of these pumps with a motor-drive. A steam-driven set would be arranged in a manner similar to the twin set of air pumps shown in Fig. 5, the only difference being in the design of one of the pump barrels and its valve box. This arrangement of combined air and circulating pump is, however, rather costly, owing to the air pump having to be made of much larger size than would otherwise be necessary, for the speed of the combined set is limited to what the circulating pump will bear. The air pump alone could easily be run at from two and one-half to three times the speed of the circulating pump.

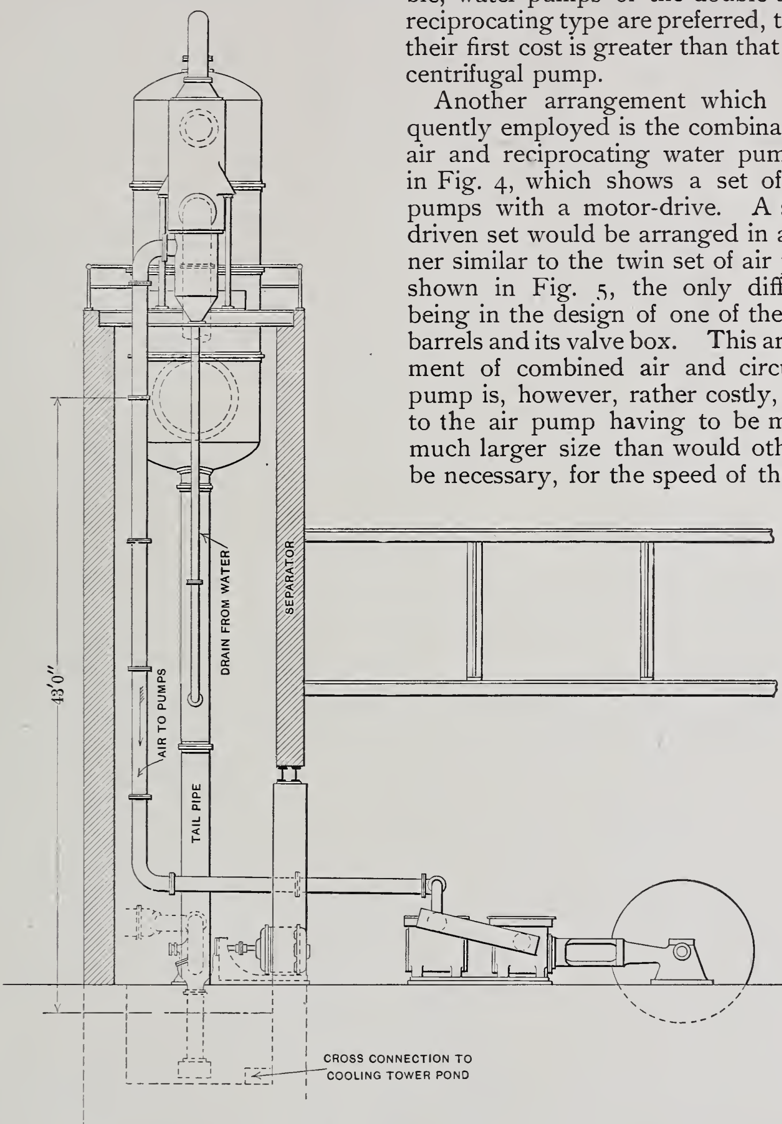


FIG. 7.—A SIDE ELEVATION OF FIG. 6

Where the first cost of plant is of

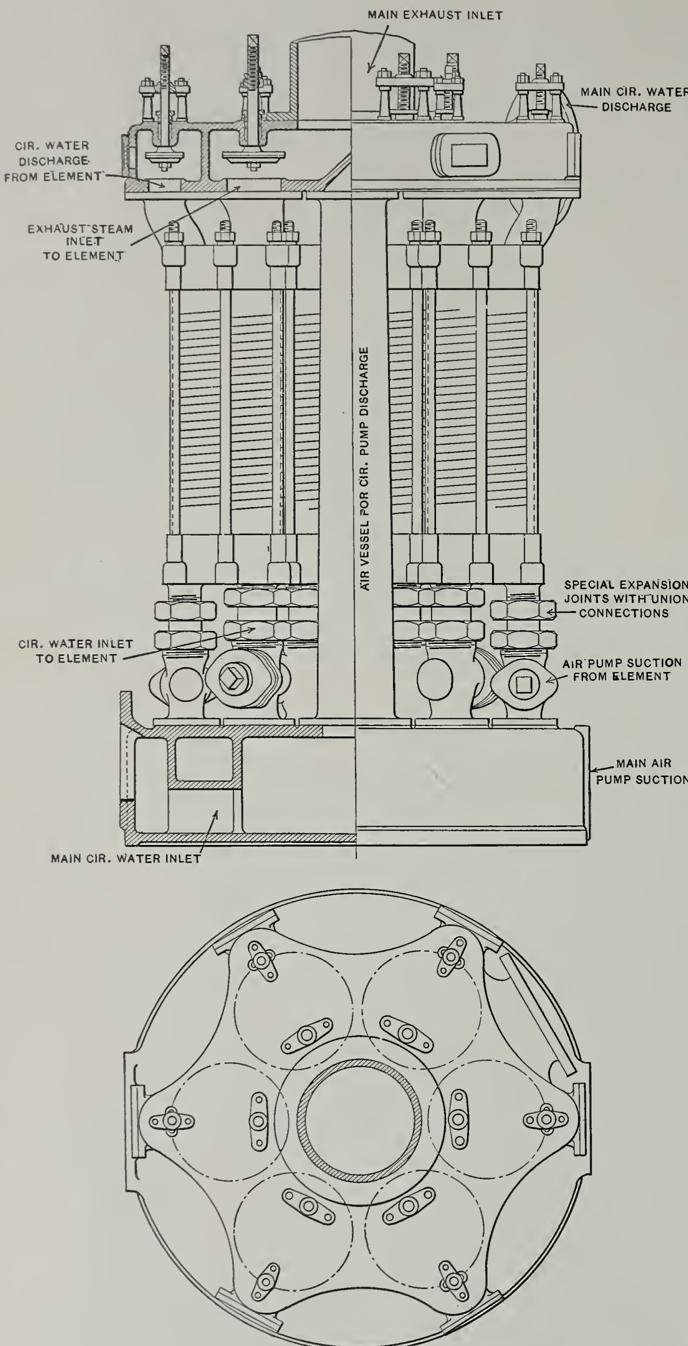


FIG. 8.—SIX-ELEMENT CONCENTRIC SURFACE CONDENSER, MADE BY THE CONCENTRIC CONDENSERS, LTD., HYTHE BRIDGE, COLCHESTER

prime importance, both the air and circulating pump (if the latter is of the centrifugal type) can be driven by the same engine or motor, the circulating pump being directly connected to one end of the engine or motor shaft and the air pump being driven by reduction gearing from the other end. For turbine installations where a specially high vacuum is required, the Mirrlees, Watson Company, Ltd., frequently employ air pumps on the dry air principle, the condensed steam being dealt with by a separate water pump.

Where the temperature of the available cooling water is high and a good vacuum is still required, condensers of the counter-current jet type are recommended, fixed at such a height that it is impossible for the discharged water to rise in the condenser tail pipes to the level of the exhaust inlet. The condenser is fitted with suitable trays, the injection water falling over these and forming a number of cascades through which the steam passes in an opposite direction. The incondensable vapours are taken out at the top of the condenser, close to the cold water inlet, and, therefore, at maximum density and minimum volume. Such an arrangement is shown in Figs. 6 and

7. The air pumps are in two sets, of horizontal, cross-coupled type, the steam cylinder being connected to one crank and the two air cylinders to the other.

Counter-current condensers, of course, have the advantage that they better utilise the minimum temperature of the circulation water, for the flow of this is contrary to the direction of flow of the steam, and the final condensed steam with its load of air leaves the condenser where the cold water enters it. Perhaps no condenser takes so little space as the multi-annular surface, counter-current condenser of the Concentric Condensers, Ltd., of Hythe Bridge, Colchester. In this condenser a number of brass tubes, alternately corrugated and plain, are fixed concentrically between a pair of supply heads. Steam enters by the top head, water by the lower end, and the outlets are thus reversed, the condensed steam passing out at the end where the water enters.

These end castings are chambered in an ingenious manner to admit the steam and water to the alternate concentric spaces. It is claimed that these condensers do not occupy more than a sixth of the usual space required for a surface condenser, and that, whereas an ordinary condenser of, say, 110 H. P. capacity will contain 1325 separate pieces, there are only 55 pieces in a concentric condenser for equal duty. One condenser is made up of a number of elements which are all exactly alike and coupled up to a common head and tail-piece. Thus, in the condenser illustrated in Fig. 8, there are six elements collected in a space 3 feet 6 inches diameter and about 5 feet 6 inches high for 550 I. H. P. The corrugations of the alternate tube affect both steam and water, and compel turbulent flow to take place with full surface efficiency. These condensers can be supplied, of course, with any air pump suitable for surface condensers generally.

It is claimed generally for this concentric condenser that it weighs only 48 pounds for an element of 20 H. P., and occupies but one-sixth of the usual space; that it can be taken apart in a few minutes and the tubes cleaned, and that it cannot be put together wrongly. The joints do not fail, because the bolts all have a stiff spring to take up expansion, and all the tubes expand alike, because all have one side to water and the other to steam. A few spare tubes alone need to be kept in stock, and all tubes are exact as to length, and, therefore, interchangeable with any other tube of the same diameter.

Large numbers of engineers are now making the Edwards type of air pump. In Fig. 10 is seen one of these pumps made by Messrs. Isaac Storey & Sons, of Manchester. In this pump, foot and bucket valves are done away with, and the water is caused to enter the pump by the mechanical action of the conical bucket, which, working in conjunction with the conical base, displaces the water, causing it to travel round the specially designed guiding edge and pass through the ports at the bottom of the barrel.

On the down-stroke a vacuum, as perfect as the water temperature will permit, is generated in the space between the bucket and the delivery valves. Into this space, as soon as the ports open, the air from the condenser passes, and immediately afterwards the water is mechanically projected at a high velocity into the barrel. The pump is so placed, relatively to the condenser, that the water flows continuously by gravity into the base of the pump, and there is a clear passage for the air over the top of the water. On the up-stroke, the ports are closed by the rising bucket, and the air and water are discharged in the ordinary way through the valves at the top of the barrel.

Owing to the mechanical action referred to above, the pump has a constant quantity of water to deal with at each revolution, and consequently any shocks due to sudden flooding are eliminated. In the arrangement of Fig. 10 the condenser lies at the back of the pumps. These are electrically driven. There are two Edwards air pumps on the same shaft as the circulating pump, which is double-acting.

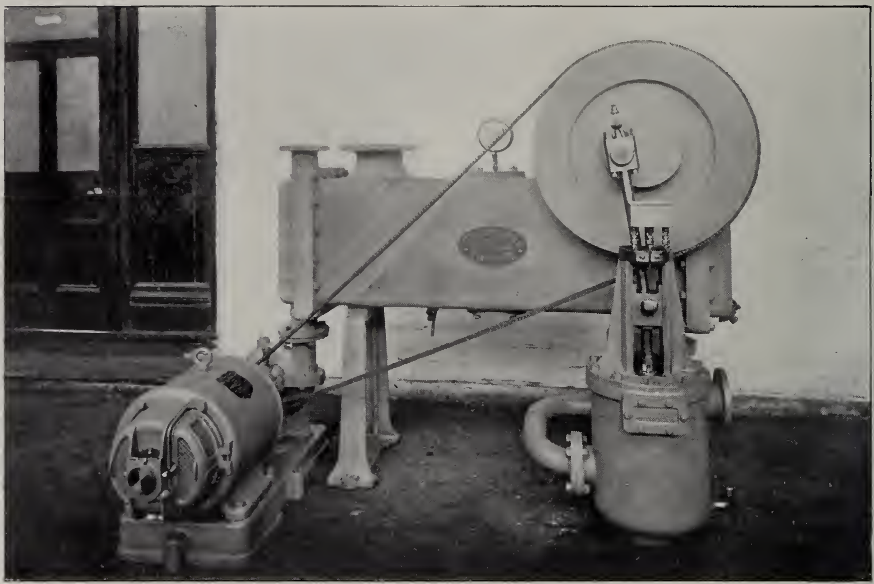


FIG. 9.—A CONDENSING PLANT WITH ELECTRIC ROPE DRIVE, MADE BY ISAAC STOREY & SONS, LTD., MANCHESTER

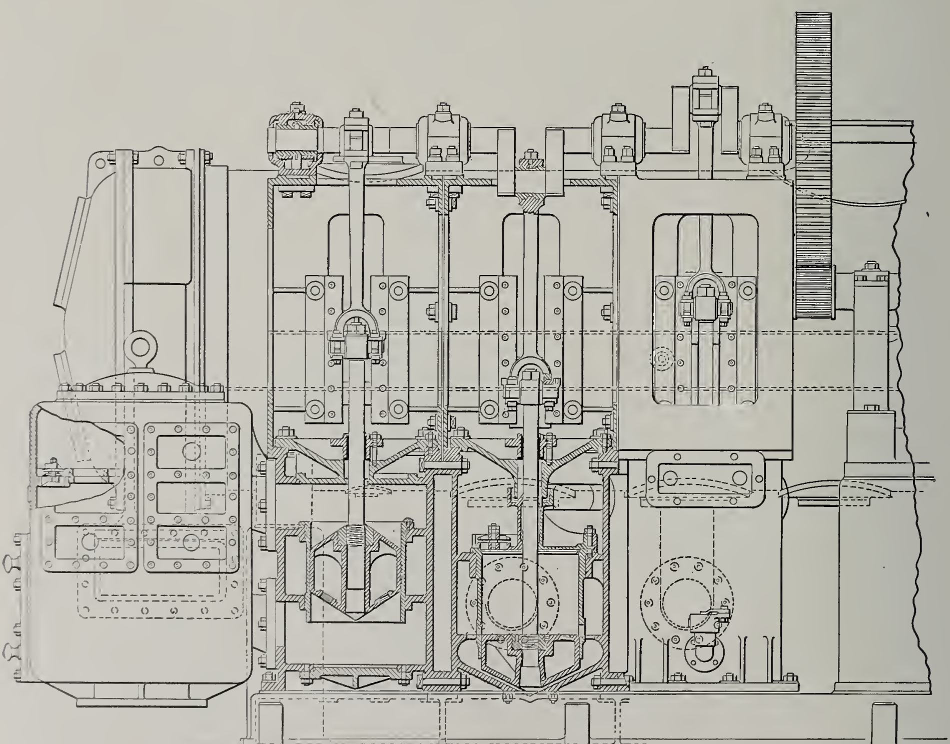


FIG. 10.—AN ELECTRICALLY DRIVEN INDEPENDENT SURFACE CONDENSING PLANT MADE BY ISAAC STOREY & SONS, LTD. THE ELECTRIC MOTOR IS NOT SHOWN

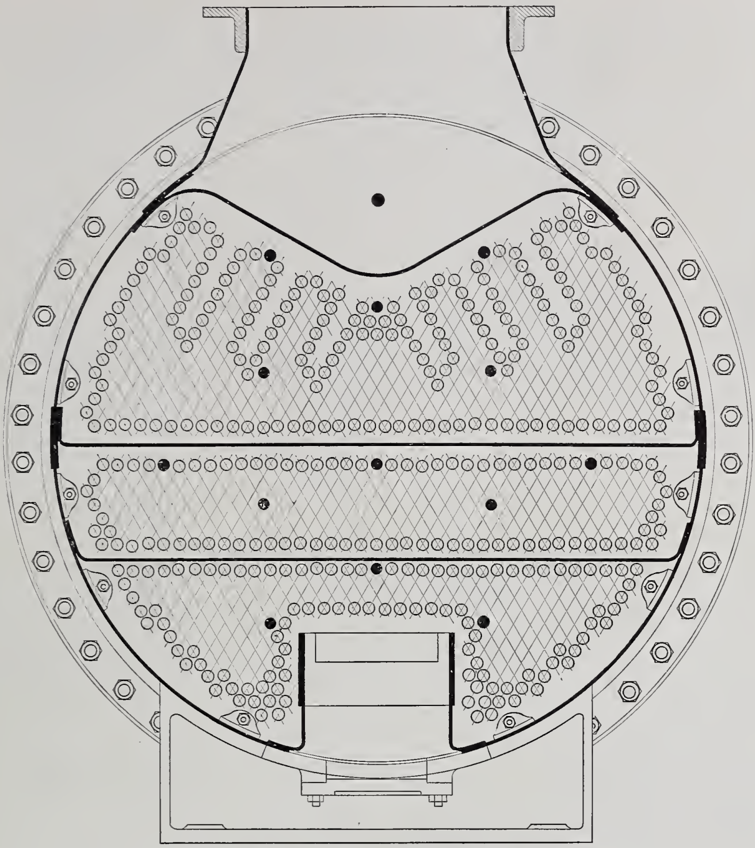


FIG. II.—A SECTION THROUGH THE CONDENSER

In the sectional view of the condenser, Fig. 11, it will be observed that the omission, as described earlier, of several rows of tubes has been carried out with the view of providing a larger exposure of tube surface, to allow easier access of the steam to the body of the numerous tubes. The baffle plate under the steam entrance is also bent to afford a larger surface of perforations which distribute the steam throughout the condenser. This distribution is very essential to the efficiency of the condenser. Without it, the tube surfaces are not swept by the steam, and they become surrounded, it may be supposed, with quiescent air, and become seriously ineffective.

In Fig. 12 a small jet condensing set of Edwards air pumps with a rope drive is shown, as made by Isaac Storey & Sons. Fig. 9 shows a small motor-driven set, and in Fig. 13 is shown the same firm's very similar design to that of Fig. 10, but with steam power drive.

Where water is not in abundance, it becomes necessary to cool it for repeated use. There are various ways of doing this. The oldest and simplest is to expose it in a pond of considerable area, where it loses heat by radiation and the action of the wind. Often the pond has placed round it a shallow trough along which the circulating water flows before it gets back to the pond. In any case it is so arranged that, if possible, all the water in the pond shall pass through the condenser once before any of it has twice passed through it. But ponds occupy more land than is always available, and hence arose the modern cooling towers now so extensively used.

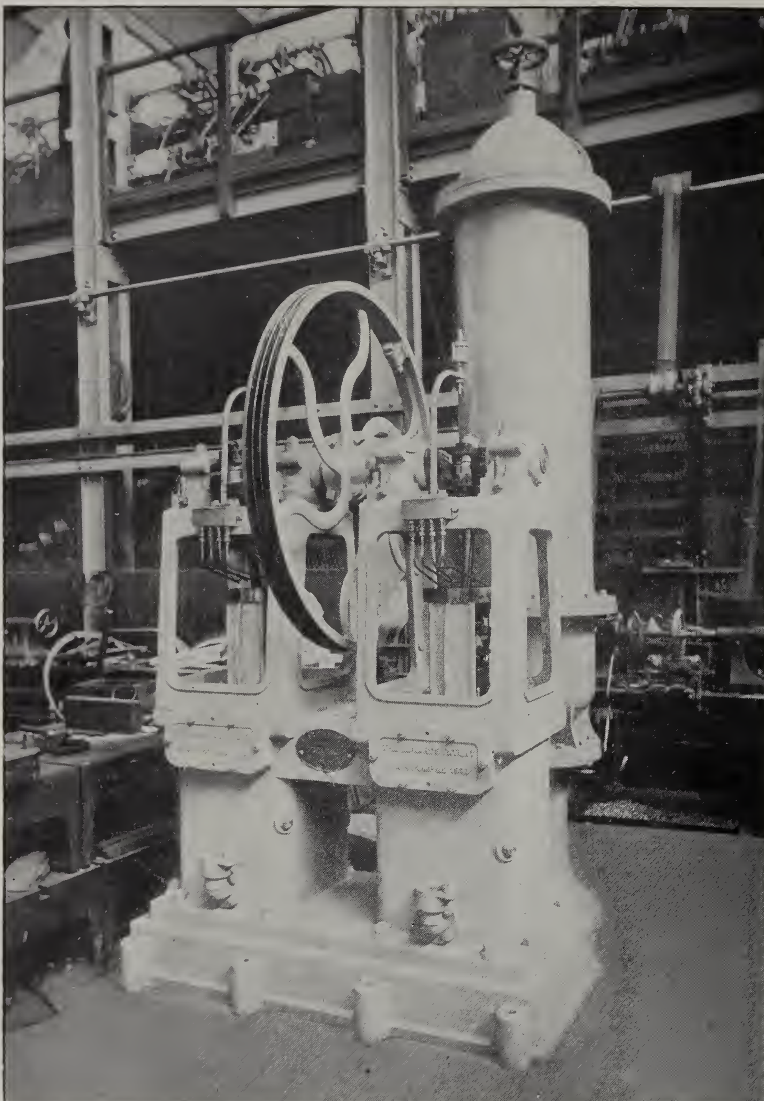


FIG. 12.—A ROPE-DRIVEN JET CONDENSER SET WITH EDWARDS TYPE PUMPS, MADE BY ISAAC STOREY & SONS, LTD., MANCHESTER

Some of these consist of large areas of suspended thin boards down which the water to be cooled is allowed to trickle in thin sheets exposed to the wind. In other cases the tower is enclosed and acts as a chimney up which a powerful draught of air is created and meets the heated water descending in thin streams, distributed over the extensive surface of many tiers of small earthenware pipes or galvanised wire mats, or split, short pipes of steel.

However arranged, the object aimed at is the same, to expose a very large surface of water to a well-divided column of ascending air, and the principle of action is also the same, for each pound of water, carried off by the air, must carry with it 966 units of latent heat and a few units of sensible heat,

according to the temperature at the top of the tower, which will usually be about that of the condenser, or, say, 100° F.

Each pound of water will, in fact, carry off, in round numbers, 1000 British thermal units, and the air necessary to carry off one pound of water will be about 55 pounds, more or less, according to atmospheric conditions. As each pound of air heated, say, 40° will carry off about 10 heat units in an ordinary case, it may be calculated that, for each pound of water which disappears, the mixed air and water vapour will carry off between them 1000 + 250, or 1250 heat units, from which figure may be calculated the effect of a tower. that may be quite successful in the dry atmosphere of one place will fail to give good results in another. Wherever people past middle age have the fresh colour due to a damp climate the provision of cooling towers must be more liberal, in order to compensate for the moisture in the atmosphere.

Usually less water will disappear than the weight of feed water condensed. The chief trouble with cooling towers is, perhaps, where the water contains lime or other salts in solution. The water in such cases should be supplemented by all the rainfall caught on the premises, and it may even be necessary to soften for lime scale, because the concentrated water will cause incrustation in the condenser tubes which can be cleaned off only by acid.

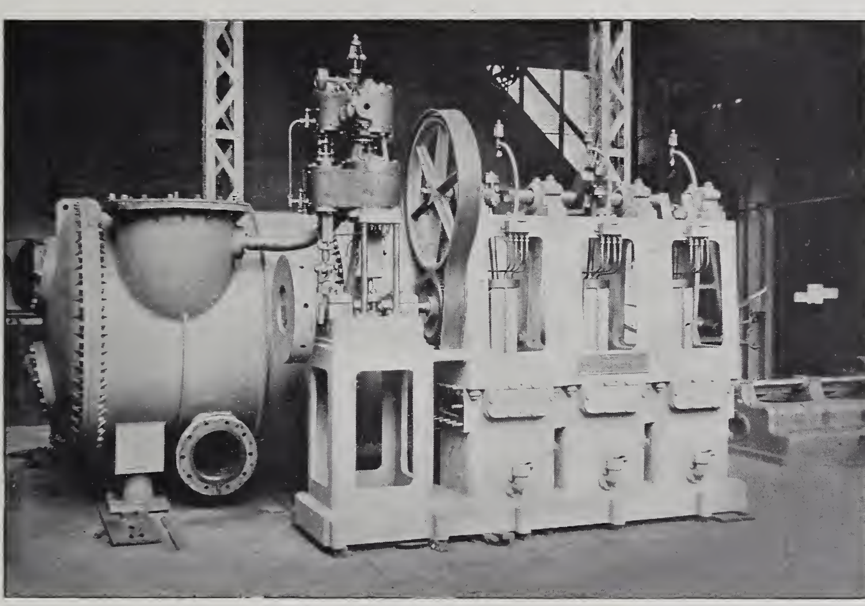


FIG. 13.—CONDENSER WITH AIR PUMPS DRIVEN BY HIGH-SPEED COMPOUND ENGINES. MADE BY ISAAC STOREY & SONS, LTD.

Towers are now very often assisted by large air propellers, which compel air to enter the base of the tower and render the action independent of atmospheric conditions, so far as up-draught is concerned. Towers are apt to fall off much in misty, damp weather, and they are a form of apparatus whose effects must not be assumed at all universal. A given tower for 4000 H. P. of steam

The tower shown in Fig. 14 is that made by the Wheeler Condenser & Engineering Company, whose standard type of tower is built under the Barnard patents, and consists of a rectangular steel shell, 30 or 40 feet high, built on a girder framing, over a concrete or brickwork tank, which acts as a reser-

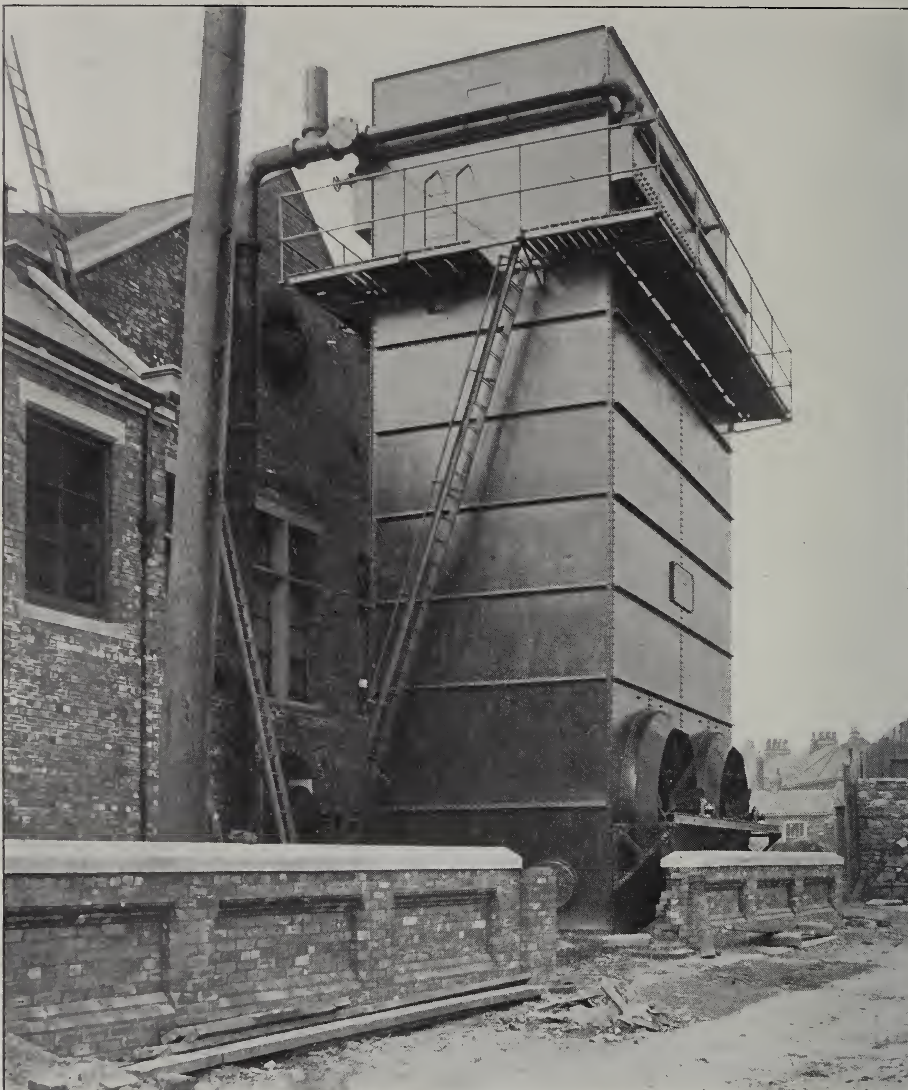


FIG. 14.—WATER-COOLING TOWER AT THE SUNDERLAND ELECTRICITY WORKS. INSTALLED BY THE WHEELER CONDENSER & ENGINEERING CO., LONDON

voir for the circulating water. To supply the air necessary for the cooling effect, one or two air impellers are fitted, according to the size of the tower. These require only a small amount of power to drive them and ensure a satisfactory cooling effect under all atmospheric conditions. The cooling surface or medium is composed of woven steel wire matting, five mesh to the inch, 19 B. W. G. steel wire, heavily galvanised after being woven. The surface, though considerably more expensive than other systems on the market, exposes a very large area of heated water to the cooling and evaporative effects of the air currents, while the material of the matting is very durable, if the galvanising is carried out in a thorough manner.

One of the most important items in a

cooling tower is the distribution system, and in this respect towers should be very carefully designed. In the Wheeler tower the water from the condensers is delivered into two or more main troughs, and is there checked by a series of baffles, to ensure a steady and quiet flow. From these troughs it drops through a series of holes into a large number of small *U*-shaped troughs, which, in turn, are perforated with smaller holes, delivering the water in a perfectly uniform manner over the entire surface of the matting.

Fan or forced draught type towers are considered to be more satisfactory in British practice, owing to the British atmosphere being always in a state of high saturation. In dull and foggy weather especially it is necessary that a very large volume of air should be put through the tower to obtain the necessary cooling effect. On dry days, when the saturation point is low, the fans can be run at a slower speed or stopped altogether, according to the state of the atmosphere.

For stations and factories where it is not so essential that the highest possible vacuum should be maintained, natural draught or open-type towers may be used, the first consisting of a rectangular shell with the cooling and distributing system already named, with the exception that instead of the tower being fitted with fans, a cylindrical steel flue or chimney is built above it to produce the necessary up-draught of air through the tower.

An open tower consists of an open girder framing, with no enclosing structure of any kind; this girder work carries the distribution system from which is suspended the cooling-mat surface. The open type of tower is the cheapest. In all types the same distribution and cooling surface is employed, this being the principle relied on to secure high volumetric efficiency, the ground space occupied being from one-sixth to one-eighth of the space required for wooden towers.

As an instance of this, it may be noted that the space occupied by a fan draught tower dealing with the circulating water from a condenser of 30,000 pounds steam capacity per hour, being equivalent to 2000 H. P., is only $14' \times 16' \times 40'$ high. A tower of this size includes two 10-foot diameter fans mounted right and left-handed on one shaft, and requiring a maximum of 24 H. P. at full speed, the average amount being generally considerably less, owing to it being unnecessary to run at full power on dry days. The gross weight of this tower complete is about 60,000 pounds.

As another illustration,—a tower of half this capacity, namely, 15,000 pounds of steam per hour, or, say, 1000 H. P., measures $10' \times 12'\ 3'' \times 39'\ 6''$ high, weighs 3900 pounds, has two 8-foot fans, and requires 14 H. P.

The smallest size tower usually built is suitable for 1000 pounds of steam per hour, or about 45 H. P. This tower is $4'\ 3'' \times 3'\ 3'' \times 30'\ 3''$ high, weighs 10,000 pounds, and has one 3-foot diameter fan, requiring about 1½ H. P. maximum.

To be concluded in the November number

THE WATER SUPPLY OF MODERN CITY BUILDINGS

PART I.—GENERAL CONSIDERATIONS

By Wm. Paul Gerhard, C. E., Mem. Am. Soc. M. E.

THE mechanical equipment of modern large buildings has been the topic of many discussions in recent years, but while much attention has been given to the steam boiler plant, the heating and ventilating system, the elevator equipment, the electric light and power installation, and the refrigerating machinery, the water supply and the incidental fire protection of such buildings are usually passed over with only a few words; and yet of all their complicated and elaborate engineering equipment, the water supply plant is second to none in importance. Not only is the supply of wholesome water for drinking a very essential sanitary requirement, but the running of the boilers, of the hydraulic elevators, of the refrigerating and ice-making machinery depend upon a proper and abundant water supply.

A modern large building, be the same an office or other commercial building, a department store, a hotel, or a hospital, requires the planning and construction of a water supply system equal to, or even more intricate than, that for a town of good size, for the buildings named may be aptly considered as small communities whose many needs and requirements for comfort and convenience must be carefully studied and provided for by the engineer, if the building is to be considered suitable for the purpose for which it is erected, and if it is not to prove commercially a failure, where it contains offices let to tenants.

Water is required for many and varied purposes, such as for drinking and for cooking, at sinks and drinking fountains; for ablutions in lavatories, bathtubs, shower and spray baths; for washing purposes, in the laundry; for the boiler supply; for the running of the hydraulic elevators; for the ammonia condensers of the refrigerating plant, also for the ice-making apparatus; for the flushing of the water-closets, urinals and slopsinks; for the washing of windows and of floors; for the sprinkling of sidewalks; for ornamental fountains; and last, but not least, for fire-extinguishing purposes. For some of the purposes named hot as well as cold water is required, and for drinking purposes the water is frequently cooled artificially. Special apparatus for distilled, for sterilised and for aerated or carbonated water is required in the modern hospital. Sometimes water of different degrees of purity is provided for; thus, deep-well water, even if unsuitable for drinking, may be utilised for the ammonia condensers and for the washing of floors and windows; a salt water supply is in some cases provided for flushing out the fixtures of toilet rooms and for sprinkling and fire service.

Whatever the character of the water supply may be, three matters of paramount importance interest us, namely, the quality, the quantity and the pressure. The water must be pure and wholesome, it must be available in ample volume, and it must flow on all floors of the building under a good, though not excessive, pressure. In a well-designed water supply plant all three conditions must be fulfilled. Where only one or two are provided for, while the others are lacking, the system must be considered as imperfect.

In arranging for the supply of city buildings, we are compelled to take the water as it comes from the street mains, unless we choose to take the rather un-

certain course of providing an artesian well supply, which more often than not proves a failure. If we take the city water, we cannot control any of the three requirements named above. Should its quality not be above suspicion, it must not be used for drinking purposes without previous filtration or distillation; if the water has many suspended impurities, or is muddy and turbid, it will foul the house pipes and tanks and leave deposits in the steam boilers; therefore means must be provided to clarify it by straining it in large filters.

If the pressure of water be insufficient, it will fail to supply more than the lowest floors directly, and the bulk of the water used in the building must be pumped. If the street mains be too small, the quantity available per minute will be insufficient, and provision must be made in the building for the storing up of a large volume in storage tanks (both in surge tanks and in house or pressure tanks) in order to maintain a sufficient supply during the hours of maximum consumption when the supply available from the city connection will be smallest.

The water supply plant for a large building comprises taps or connections with the street mains; service pipes to carry the public supply into the building; fish traps to prevent any obstructions such as eels or fish in the street mains from getting into the house pipes; gate and check valves to control and shut off the entire supply; water meters to measure the consumption for the purposes of establishing the water charges or rates to be paid by the owner; water filtering apparatus to clarify and render suitable for use the entire water supplied by the street mains; suction or surge tanks into which water flows from the street connections to be stored and made available for the pumps; water pumping apparatus comprising house and fire pumps to make the water available for the upper stories and for fire service; storage tanks to cause a flow of water under suitable pressure,—roof tanks, intermediate tanks, or pressure tanks; water distribution lines, forming either a header or a circuit system with controlling valves; supply risers for cold and hot water, and branches to the plumbing fixtures, to which are often added circulation lines for the hot water; besides numerous other accessories, such as water heaters, with sight or recording thermometers and thermostats; gauge boards, with steam, air and water pressure gauges; air compressors and air storage tanks; and finally the necessary fire protection and fire extinguishing apparatus, comprising fire pump, inside lines of standpipes, with valves, hose and fire nozzle, reels or racks to support the hose, and outside or street connections for the Fire Department.

Before taking up more in detail some important parts of such a water supply plant, a few general considerations regarding quantity, quality and pressure may be helpful to a correct understanding of the subject.

In planning the water supply for a proposed large building, the first thing to determine is the maximum daily amount of water required. This will necessarily depend upon the character of the building, its size, number of stories, and the number of tenants, both temporary and transient. Where the building is intended for occupancy day and night, as for instance in the case of a hotel or a hospital or institution, a larger volume of supply is required than where the building is occupied for only a certain number of hours per day, as in an office or commercial building. It is further a matter of observation and record that the consumption of water in a building increases with the number of plumbing fixtures provided. The greater the number of faucets or taps, the more water will be consumed, or rather wasted, through faucets carelessly left running.

A fair and generous average allowance for domestic consumption per capita per diem would be sixty United States gallons of water. If the total number of persons occupying the building can be ascertained beforehand with any degree of accuracy, the supply required by them can be estimated, but to this quantity should then be added the supply for the boilers, which is very large

where steam is generated not merely for heating, but also for power purposes, the supply required for high pressure boilers being about four gallons (30 lbs.) per horse-power per hour. A further increased allowance must be made if the building is to contain a refrigerating plant, for if kept constantly running, as is usual where refrigerators and ice boxes are kept cool by brine circulation, the amount of water consumed is sometimes very large, being from 1½ to 2 gallons of water per minute per ton of refrigeration, according to the temperature of the water.

In large buildings it is also of much importance to keep an abundant supply of water under suitable pressure available for fire extinguishing purposes, besides a further supply in large surge or suction tanks, to be drawn upon by the pumps.

It is a matter of record that the more plumbing there is in a building, the higher will be the per capita consumption and the preventable waste. Waste of water does not occur in tenements or homes of the working class, but rather in the houses of the well to do people.

Among other buildings where water is used most lavishly are the hospitals for insane patients, the consumption running as high as 150 and even 200 gallons per capita per day. According to recent sewer gaugings, the consumption at the Kings Park, L. I. State Hospital, including the laundry water, was 132 gallons per day, and at a State insane hospital of West Virginia, it was 91 gallons. These figures are obviously much below the actual consumption, for the reason that water used for sprinkling lawns, washing carriages and stables, and watering horses and cattle does not reach the sewer. In a recently opened large general hospital in the city of New York, the writer found, by actual meter measurement, the per capita daily consumption to be at the rate of 305 gallons,—a very excessive consumption, due partly to unusual carelessness in keeping faucets running, and partly to the running of an ice-making and refrigerating plant.

The annual reports of water works superintendents of cities are full of complaints of the waste of water which goes on not only in winter time to prevent plumbing from freezing, but at all other seasons. It is this constant waste, due either to wilful negligence, or to defective and leaky plumbing which causes the exorbitant consumption of water of American cities. In one report on waste of water, which has just reached the writer, it is stated that "where no charge is made for water used in public buildings it often happens that little or no attention is given by the officials in charge to prevent the extravagant use or waste of water. For this reason the quantity used is sometimes *very large.*" Institutions which receive the water free of charge, are apt to overlook the fact that the water which they waste so recklessly represents to them a considerable money expenditure in their consumption of coal, first for the pumping of the largest part of the water to tanks, and second for the heating of one-third to one-half of the amount.

Water used with the ammonia condensers of a refrigerating plant should never be allowed to run to waste into the sewer, yet this waste occurs in some buildings. Such water, being clean, can generally be utilized, either in the feed water heaters for the steam boilers, or it can be pumped into the hot water tanks. It should not, however, as has been suggested, be used for the flushing of plumbing fixtures, for it is warm water at from 80 to 90 degrees Fahr., and experience has shown that the use of it for flushing water-closets, urinals, and slop-sinks, is objectionable. Either cold or very hot water should be used for this purpose.

Regarding waste of water by faucets carelessly left running, few water takers stop to think that "sufficient water will flow in 24 hours through an orifice no greater than a lead pencil, under an average pressure, to furnish an ample domestic supply for 360 persons, and that more water will leak through an orifice the size of an ordinary pin than would be used by a fairly economical family of five persons.

In the face of such indisputable facts

regarding water waste, would a conscientious engineer be justified in making allowance for an expected extravagant waste of water in the figures which he uses as a basis for calculation of the principal dimensions of a proposed plant for a building? Waste of water is both wanton and costly; it must be reduced or kept down, and the best way to accomplish this is to charge for the water by meter rates. No engineer should use figures indicating a very wasteful use of water in designing or laying out a water plant.

In a recent engineering discussion, the following rough estimates of allowance for water in office buildings was given:—

2/10 gallon per square foot of office space for ablutions (sinks, lavatories).

4/10 gallon per square foot of office space for flushing water-closets and urinals.

2/10 gallon per square foot of office space for refrigerating plant.

But it would seem better to base calculations on the number of plumbing fixtures, or upon the number of occupants, or both, rather than to average them by the floor space.

The data and facts mentioned should guide an engineer in the determination of the sizes and number of water taps or street connections. It is also necessary to take into consideration the size of the street main, and whether that main is a low or a high-pressure main. Lastly, the length of the service pipe or house connection plays an important part in the volume of supply, for the longer the service or branch, the greater will be the friction of the water flowing in the pipe, and the less volume of water will be received through a pipe of given size, under the same pressure. A 2-inch lead or iron service pipe, 35 feet long, will, under 30 lbs. pressure, discharge 250 gallons of water per minute; but if the length of service pipe is 100 feet, the other conditions remaining the same, it will supply only 160 gallons.*

The ordinary size of tap permitted by Water Departments for a private dwelling is one-half or five-eighths inch in diameter; for larger mansions three-quarter-inch and one-inch taps are conceded only under the condition that the water be supplied by meter measurement. Such sizes are, of course, quite inadequate for the supply of the large buildings to which reference is made in this article. For these the sizes of taps vary from two to four inches.

Often more than one such large tap is required. Where the building extends from one street to a parallel street in the rear, it is a good plan to provide a tap in each of the streets, so that when one street main is temporarily shut off for repairs or for making connections, the building continues to receive its supply from the other tap. It is also well to remember that at least 25 per cent. more water may be obtained by enlarging the service pipe immediately on the house side of the street tap. Thus, for a large group of hospital buildings, occupying an entire city block, the writer provided for four 4-inch connections, but the Water Department having refused permission for this contemplated supply, and, having authorized the insertion of only four 2-inch taps or branches, each service main was increased to 4 inches, so that four 4-inch mains were brought into the pump room, thereby securing a much larger supply of water. In a hotel building having nineteen stories above the street and four stories below the street or sidewalk level, the Water Department granted the use of two 2-inch branches and one 4-inch branch, which were enlarged to 4 and 6 inches, respectively, to insure a better supply. For another, still larger, hotel two 4-inch connections and one 6-inch connection are contemplated. For a court house and post office building, occupying a floor area of 36,400 square feet (an entire block) four 2-inch taps and one 4-inch connection (the latter for the boiler plant) were planned.

Where the supply is to be filtered, the available quantity will depend primarily upon the capacity of the filters selected. These should, therefore, al-

* See Table of Flow of Water in House Service Pipes, in Kent's Mechanical Engineer's Pocketbook, page 578.

ways be chosen generous in size and sufficient in number. The service connections should be as short as practicable, and therefore filters and surge tanks should be located in the cellar or subbasement near the outer walls of the building.

Suction tanks are provided for various reasons,—to store a supply of water available for the pumping plant, to prevent the pumps from drawing directly from the filters, which practice is not advisable, and also to prevent the pumps, when working, from interfering with the direct supply to the fixtures in the lowest stories of a building. Surge tanks may be either open or closed tanks, and both have advantages and disadvantages. The supply, if filtered, remains uncontaminated when stored in closed tanks, and as suction reservoirs for the pumping machinery closed tanks also are generally to be preferred. Open tanks, of course, require the supply to be controlled by either several ball cocks or by large float valves.

The delivery of water from taps of various sizes, under various pressures and for different lengths of service pipes, may be calculated from hydraulic formulæ or determined by means of tables or diagrams. It is, however, much to be desired that the flow of water through service pipes be determined by actual hydraulic experiments. The results, if published, would form the most reliable guide for engineers in planning the water supply of large buildings.

As to the quality of the water coming from street mains, this is often far from satisfactory from a sanitary point of view. To overcome this fault it has become a common practice to filter the entire supply as it enters the building through the main service pipe. Filtration is nearly always accomplished in so-called mechanical or closed pressure filters; the open or gravity filters, used in water works systems, are not well adapted for buildings.

Mechanical filters consist of single or double cylinders, made of either wrought or cast iron, and filled with sand, charcoal or other filtering medium, to which sometimes an alum-feeding attachment is added. The process of filtration is largely a straining process, which clarifies the water without, however, rendering it quite germ free, but it is worth considering, because it makes the water better adapted for use in the steam boilers, prevents the usual disagreeable deposit of mud in the flushing cisterns, and keeps the supply pipes clean, thus, in some measure, preventing the loss of pressure in them.

The continuous working of the filter depends upon the frequency with which its periodic cleansing and washing is attended to. This washing process is somewhat tedious and slow, and requires a large volume of water to thoroughly clean the filter beds. Unless the washing of the filters is faithfully and regularly performed, the filter batteries soon lose their efficiency. A pressure gauge, attached to the water main before it enters the filter, together with a second gauge on the main carrying the filtered water, will at once indicate, by the loss of pressure, whether or not the filter requires washing.

For the drinking water supply, which is comparatively small in volume, the best practice calls for special filters, such as filters in candle form made of infusorial earth, or else of natural filter stone, usually in connection with a plant for cooling the water. While it seems, at first glance, desirable that the municipality should provide filtration works rather than to leave it to the individual water consumers to filter their supply, unusual precautions must be observed where the entire supply for a city is filtered, to keep the water pure *after* filtration. The water must be stored in covered storage reservoirs, which involve quite an expense in construction, for in open storage reservoirs the filtered supply would nearly always become exposed to contamination, and where the water mains in the streets are old and full of deposits of mud, clay and iron rust, the filtered supply soon becomes turbid and dirty, and, as delivered into buildings, it would in most cases necessarily have to be refiltered before being suitable for use. Hence, in some instances it is advisable to provide two

supplies,—one for potable water, and the other for such uses of water where filtration would seem unnecessary.

Instances may occur when it will be more economical not to filter the entire supply for a city, but to leave the purification of part of it to the individual owners of buildings. There seems to be no reason why this should not even be regulated by law. If health regulations can compel a landlord to abolish cesspools and wells, to provide soil and vent pipes and traps, to instal water-closets with cistern flush, what is to prevent their going a step further and requiring drinking water to be filtered?

To be concluded in the November number.

BUILDING A BATTLESHIP IN TWELVE MONTHS

AND AT HALF THE PRICE NOW PAID

A Criticism of American Methods

By Joseph R. Oldham, N. A.

IN the annual report of the Chief of the Bureau of Construction and Repair of the United States Navy it is stated, over the signature of Rear-Admiral F. T. Bowles, that the time required for the construction of a battleship in the United States "compares not unfavourably with the best results obtained in foreign countries, namely, Great Britain and Germany." Though this may be so, it by no means follows that the first-named country should be satisfied if her warships be built within the time required by the old nations of Europe for the construction of similar ships.

It may, however, appear that it requires a much longer period to build such vessels in America than is required by some European nations.* The battleship *Rivadavia* was constructed so far as to be launched, by Messrs. Ansaldo & Co., of Genoa, Italy, within thirty weeks from the time the keel was laid. A much larger battleship, the *Libertad*, was launched from the Naval Construction Works, at Barrow-in-Furness, within forty-one weeks from the time the keel was laid. Larger warships than either of these have been built in Great Britain in less time than two years. The author has seen a twin screw steamer of about 5000 tons register, with all the complicated mechanism required by a cable-laying steamer, constructed, launched and completely finished within three months from the date of the contract.

Messrs. Charles Mitchell & Co., the builders of that vessel,—the *Hooper*,—were enabled to accomplish that feat in ship construction only through having matured designs and complete detail plans to work from, which plans were not improved upon nor altered during construction. Those who undertook and guaranteed the fulfilment of this contract, and those who executed the work, were merely good business managers of ordinary scholastic training, and experienced shipbuilders, who had worked in the shipyards from early youth.

Plans of a large steamship have been

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* The battleship *Ohio* was two and a half years on the stocks before launching, and she will be five and a half years in completing.

so accurately designed and carefully finished, with every detail thereon, that the vessel was built and completed without any alterations or improvements of the design. The author was connected with the operating of this steamer for some years after she was built, and can say that she gave such satisfaction to her owners and others that no alterations were either effected or proposed, so far as he was aware. Now, if the large "cable" steamer just described could be built within three months, and if the largest battleships can be built in British and Continental yards within two years, is it not possible for the United States to build her largest battleships in much less time than the four or five years now occupied in the completion of these structures?

It would seem to the writer that if American engineers applied the same enterprise and energy to shipbuilding that they have devoted to mining, steel making, and bridge and locomotive building, the result would be different. As it is, America has not given her undivided attention for any great length of time to shipbuilding, and in merchant ship construction at least the country is decades behind Great Britain, both as regards the time required and the cost of construction.

Many of the world's great buildings, the large cathedrals, for instance, were not built from original, full and complete plans; such plans, if they ever existed, were doubtless lost or destroyed long before the buildings were finished; these were delayed in construction, sometimes for decades, for lack of means, materials, or men. Such conditions as these do not appertain to the construction in these days of a warship, which should be finished quickly to keep pace with the times, if not for economical reasons.

To accomplish this, the first desideratum is to have full, exact, and complete designs and detail plans of the hull. Are such plans supplied by the American Naval Bureau of Construction and Repair? The answer to this basic question is, No. The designs given to contractors are far from complete, and are not accompanied by proper detail plans. They are "general" plans, outline plans, and are commonly called "type" plans. The specifications also are outline and typical. About the only things fixed and definite about these documents are the general dimensions, the approximate displacement, armour, armament, and speed of hull. The contractor is not given much more than this to guide him in working out the design and various details of construction of a warship, though he must comply with all directions.

There may be some merit in this system, however, as it calls forth the originality and experience of the various shipbuilders of the country in the production of a ship which will redound to their credit, and if time and money were of no value it might be to the ultimate advantage of the country to continue this system.

Let us see how this works out. The work of designing a warship is very intricate, but it is not more so than the design of a large, high-speed mail steamer, which is commonly built in about half the time required to complete a warship of much less tonnage. The plans furnished by the United States Government would appear to be drawn in anticipation of alterations or improvements to be developed at some future stage in the construction of the ship, rather than as an exact definition of form and arrangement. The fact that the general plan has to be exactly arranged, that details of construction have to be designed, and working drawings made by the contractor is not the principal cause of delay; it is the continuous alterations which cause the great loss in time and money.

Let me give a brief illustration of this. The writer remembers a plan which embraced not over one-fiftieth of the length of the hull and but one element of the construction of one deck. This plan took two draughtsmen about three months to make, with the usual supervision of a foreman and the chief draughtsman. It was then submitted to the constructor at his shipyard office; the plan remained in his possession for

over two months, when it was returned to the contractors, with numerous and fundamental alterations or corrections attached to it, so much so that the plan had to be redrawn, which occupied six weeks, after which it was again forwarded to the constructor for his approval.

This approval was secured in another six weeks with only nominal alterations marked on it, and it was soon passed on to the shipyard foreman for execution. He, in turn, required some additional sketches.

This little plan, developed from good-looking plans and specifications furnished by the Bureau of Construction, required fully nine months to become an approved working drawing before a piece of metal could be cut or handled so as to go into its place in the ship. Now, instead of this system, suppose that the draughtsmen who made that plan, the foremen who supervised it and the constructor who supervised the whole had all been in the Bureau at Washington, say, for about a year before the commencement of said plan, could they not have produced it with a saving of nine months in time and considerable saving in salaries? This may not have been a very large loss, but if such loss be multiplied by 100 or even by 50, it becomes considerable.

Let it be admitted that there was some improvement in the final plan mentioned, could not such improvement have been carried over to another ship, and thus not have been lost, while the ship for which the design was made would have been a gainer in time of completion and in first cost, though possibly a slight loser in efficiency of this detail?

One of the most important causes of delay in the construction of naval vessels is the habit which has hitherto prevailed of designing vessels while they are under construction. One of the most recent specifications issued by the Navy Department requires that 253 of the most important items in construction should be built as directed, which means that at the time the specifications were written no one connected with the design for the vessel could write down distinctly just how that design was to be carried out.

In the shipyard, plans are made only to be returned over and over again as unsatisfactory, and what seemed plain enough to the shipbuilder when making his estimate becomes now so complicated that the first year's time of the contract is lost in finding a way to carry out the contract. There should be only one naval architect responsible for the design of the vessel. Now there are three parties trying to do the work, —the Bureau of Construction and Repair, the superintending constructor, and the shipbuilder, and much time is lost in trying to harmonise the ideas of these three parties to the design. As the Bureau of Construction must finally decide, the time expended by the other two parties is in many cases simply time wasted, and retards construction work on the vessel. As an illustration of this, the author has authority for the statement that work on a cruiser had to be stopped for seven months until the constructors at Washington could decide just what the course of a pipe should be.

It is not uncommon to see bulkheads, bunkers, hatchways, turrets, hawse-pipes and chain lockers materially altered after the hull is all plated and the ship ready for launching. The writer has seen the bottom cut into for fitting torpedo tubes after the launch-ways were placed, and gun ports altered after the ship was afloat.

In brief, it would be difficult to put one's finger upon a single element in the structure of some vessels and say, "this is actually finished as it was originally designed." Even the very lines are changed, and it is no exaggeration to say that material alterations are commonly effected in government ships from stem to stern and from keel to truck while building.

The workmen become demoralised by these continuous alterations. They say,—"What is the use of taking trouble over these parts or in pushing the work along? We know that it will never be carried out on these lines." The worst feature of this condition of affairs is that in many cases such changes

are mere alterations and not improvements.

It is not easy to show the actual cost of extensive and continuous alterations, and consequent delay and loss of time and money. This will not, however, be less than 50 per cent. in many cases, and it may increase the cost of construction by as much as 100 per cent. over that of a fully designed and completely described ship, constructed without any changes or alterations whatever.

It may as well be admitted at once that in a large warship, constructed within twelve months, the workmanship and finish will not be of so fine a description as is now usually obtained. But is not some of the work as at present required by the constructors too fine, that is, finer than is necessary in certain localities? I have seen good, strong work condemned and pulled to pieces simply because it did not look nice in its unfinished condition. Work which would be passed as satisfactory by an experienced surveyor of merchant ships will not be accepted by an ordinary government inspector.

It would seem, with regard to many of those composing the staff of large shipyards in the United States, as if their early scholastic training had been too comprehensive or discursive for men required to direct the construction of ships,—work, for the most part, as at present demanded, not of the finest kind,—work requiring good, practical experience and moderate accuracy to construct quickly and economically. What is meant is that there is not nearly so much close marking, fitting and adjusting required in the building of a ship as in the making of a nautical instrument, or a weighing machine, or even of a high-class steam engine.

The time is coming, however, when ship work will have to be of a much finer description. In the meantime, shipbuilders have to make money to live, and this can be done only by working quickly and as accurately as will secure good and strong work, with reasonable finish.

The finest yachts and torpedo-boats are constructed under entirely different conditions. No shipbuilder can build a "tramp" or even a large passenger steamer with all holes drilled and fittings and finish as perfect as they are on those little craft, which cost five times as much per ton as an ordinary ship.

This leads to the conclusion that a somewhat less extensive and less severe academic training will suffice for the shipbuilder of to-day than is essential for the astronomer, the lawyer or the physician. As the tendency is for the workmen to copy, and eventually to become like the men who direct them in their work, superintendents and inspectors should have good, practical experience in the shipyard. When a young man has been used to handle wood and steel, as in a shipyard, from early youth, he will in most instances acquire a taste for that kind of work. On the other hand, let him work continuously at books, and in the study of the arts and sciences, until early manhood, and he will most probably acquire a taste for such work, and probably a corresponding distaste, and consequent incapacity for arranging and directing mechanical operations, such as are involved in the construction of a ship.

Moreover, in most American colleges the curriculum is so discursive that an embryo ship constructor will be taught almost everything, or a little of everything, except that which would be of most use to him in a shipyard or on the mould loft floor. Therefore, the author's advice to a boy, compelled to make his way in the world, and who has decided to become a shipbuilder, would be to make an early start in the shipyard, and then endeavour to get theoretical instruction from a good practical naval architect and shipbuilder, after he found out his deficiencies and knew the kind of theoretical knowledge he required to become a thorough designer and constructor.

By adopting this course a young man may acquire a good general knowledge of the art and science of shipbuilding at an age when most college students are only beginning to learn the business of a shipbuilder. It would seem that the heads of departments would frequently

be better fitted for the duties which they have to perform if more of their time had been spent in the workshop and less at the school.

The author would not be misunderstood, but the extraordinary depression of the shipbuilding industry in the United States is difficult to account for; he believes in a college education,—indeed, he has one son a professor, and there are two others following in his footsteps. But for a man occupying a leading position in a shipbuilding yard it would seem as if he who had worked with tools from early youth, and then studied the branches of science which he found he required, would be most successful in pushing work along quickly and economically.

The writer knows an excellent professor who had charge of several shipyards; they all failed, and are no longer in existence. As a contrast, witness the dozen or more shipbuilders who have made large fortunes in constructing ships, but not one of whom was ever at college. So much the worse for them as men, and they know it and feel it; still they have the satisfaction of knowing that they could build ships quickly and make money in building them.

To build a large warship in twelve months it would be necessary to push the work at a much faster rate than is now usual. In doing this the structure might suffer somewhat in finish in certain parts, but this could be limited entirely to the immersed portion of the hull, inside and out. This would not make the completed ship a single degree less efficient than the most highly finished vessel afloat.

If time were not taken to cut off every superfluous sixteenth of an inch of plating edge, or bar, in the bottom construction, or off bulkheads, engine and boiler seatings and stringers, and if the practice of cutting out a curve in a solid plate to go round a corner were done away with, a little superfluous metal,—seldom more, however, than one-fourth of one per cent. of the total weight of metal in the hull,—would be left in the ship.

To compensate for this the heavy and very expensive ram-bow might be eliminated. So far as the writer can remember, the ram has not rendered any service since the days of the American Civil War, unless the sinking of several friendly ships, belonging to the same fleet as the vessel which did the ramming, be considered a service. In combat it seems as if the commanders kept their rams as far from the enemy's ships as possible. This probably evinces only reasonable discretion, as in the heat of conflict the action of ramming would generally result in the foundering of both vessels.

The contention is that the bottom of a warship has no more arduous duties to perform than that required of a first-class "merchantman," constructed with but little superfluous metal in her bottom. The ship bottom that is capable of supporting and transporting dry and perishable cargoes to all parts of the world, in all seasons of the year and under the varying conditions of loading, both as regards weight and the disposition of load, is, however, quite good enough to bear ammunition and guns, and, when locally strengthened, to support torpedo-tubes.

It would, no doubt, be difficult for the Bureau of Construction to decline plausible suggestions from talented men anxious to make improvements upon approved designs. Then there are other improvements continually suggesting themselves through foreign correspondence and "exchanges." It would be well to bear in mind, however, that some so-called "improvements" are merely alterations.

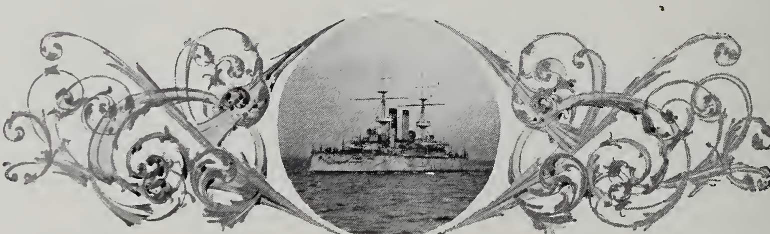
To meet these seductions, let there be always on the board at least one vessel of every type, in the designing stage, and when the modifications are presented these should be formulated on the corresponding design. That would seem to be the proper way to develop ideas. Talking and writing will not do it. Ideas must be delineated to be discussed and understood, and, when so perfected, why not let them be embodied on the latest "unapproved" design? When, however, a design reaches the "approved" stage, let it be like the

law of the Medes and Persians, which altereth not.

The ship so designed and constructed, say, in about twelve months' time, will be of a more modern type than her "improved" sister ship which may have been building for three or four years. A large ship cannot be entirely remodeled by all practicable alterations.

Therefore, the author inclines toward the opinion that the vessel which is begun and finished within a year, without any changes or alterations whatsoever, will be a more up-to-date ship than the one launched at the same time which may have been under construction for three or four years, even though she have all practicable improvements embodied in her hull.

It appears that such terms as "type" plans and "outline specifications" should be expunged from warship designs and specifications. American constructors having now had very extensive and valuable experience in designing and in constructing ships, and being in no degree inferior to the best of their colleagues in other establishments, there seems little reason why their warships should not be fully, exactly, and completely designed, drawn and described by the Bureau of Construction and Repair before reaching the hands of the builders. Then, without alterations or improvements, the best and largest warships could be constructed in America in about one-third of the average time now required for their completion.



SOME NEW CUTTER AND TOOL-GRINDING MACHINERY

EXAMPLES FROM AMERICAN PRACTICE

By Charles S. Gingrich, M. E.

THE advent of the so-called "high-speed" steels has caused, and is still causing, a most thorough and careful investigation into the cutting qualities of tools in general, and has also been the means of directing especial attention to the necessity of keeping the cutting edges of all tools thoroughly and properly sharpened. For a number of years one well-known manufacturer of small tools has been printing on his cutter lists, in bold faced type, the following words:—"Keep cutters sharp." The fact that it has been necessary to prominently display this statement on cutter lists is in itself evidence of the general laxness that has existed in regard to keeping cutting tools sharp.

The rapid progress that has been made in the use of milling machines for heavy work has also brought into general use large milling cutters of various forms, and the fact that during the past year four newly designed cutter and tool grinders have been placed upon the market is indicative of the new activity in this direction, and shows the demand for machines for quickly and conveniently sharpening all sorts and sizes of cutters.

One of the newest and most complete cutter grinders is shown in Fig. 1, which illustrates the Brown & Sharpe Manufacturing Company's new No. 13 universal and tool grinding machine. It embodies some of the main features of their regular universal grinding machines, but has special ones which especially adapt it to cutter and tool grinding. The emery wheel head has a 6-inch vertical adjustment under the control of a hand-wheel at the top, and it may also be swiveled and set to any angle. In addition to this the table may be set at an angle for taper grinding For this setting it is provided with a graduated arc, clearly shown in Fig. 1. These two swivel movements, in connection with the vertical adjustment of the emery wheel head, make it possible to bring the cutters into almost any desired position in relation to the emery wheels, which is of importance in sharpening various forms of cutters.

This universal feature for sharpening milling cutters is further extended by the universal head which is shown in use in Fig. 2, illustrating the operation of grinding the face teeth of a face mill.

Fig. 3 shows the method of sharpening the teeth of a standard spiral milling cutter. In this case the cutter is held on an arbour, one end of which is supported by the foot stock, while the other end is held in the universal head. The cutter itself is fitted with a shell, and is slid along the arbour when being ground. It will be noted that all of this cutter sharpening is done with the face of a cup or dish-shaped wheel, which gives a straight line clearance, of which we will speak later.

Fig. 4 shows the application of the machine for grinding a spindle. For this class of work the machine is fitted with power feed, and the work itself is revolved between dead centres.

One of the most interesting features of the machine is the circular grinding attachment, which is shown in use in Fig. 5, illustrating the operation of grinding the teeth of a convex cutter. The attachment is so arranged that it can be adjusted to bring the centre of

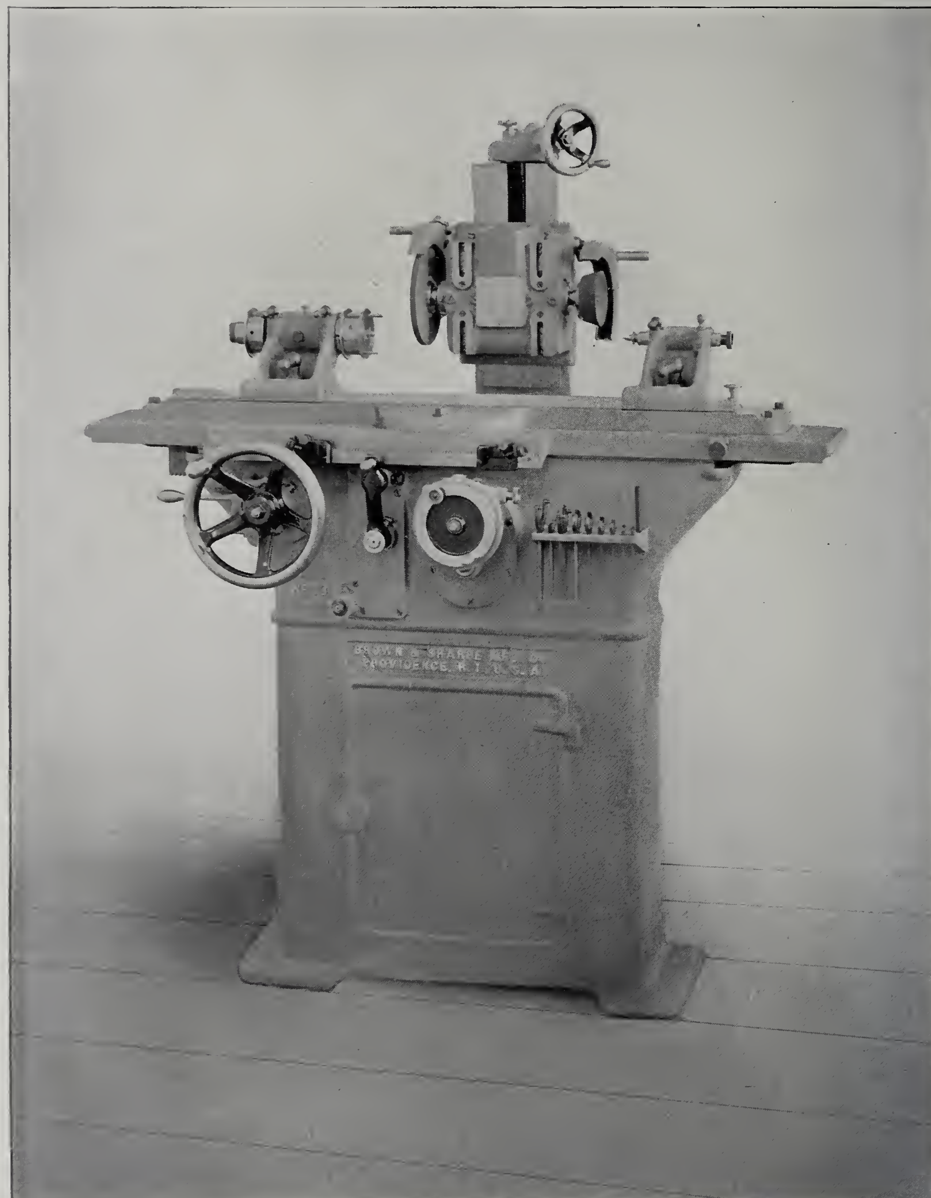


FIG. I.—NEW UNIVERSAL AND TOOL-GRINDING MACHINE MADE BY THE BROWN & SHARPE MFG. CO., PROVIDENCE, R. I.

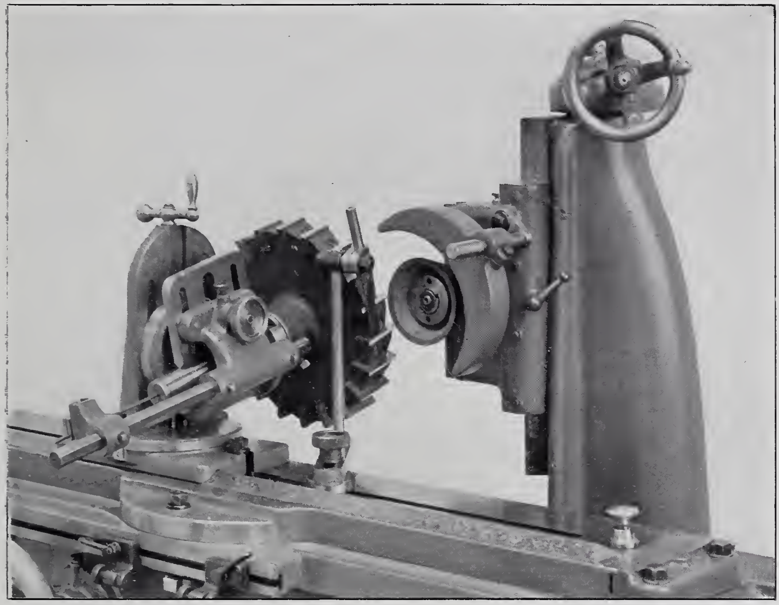


FIG. 2.—THE UNIVERSAL HEAD IN USE ON THE BROWN & SHARPE MACHINE SHOWN IN FIG. 1

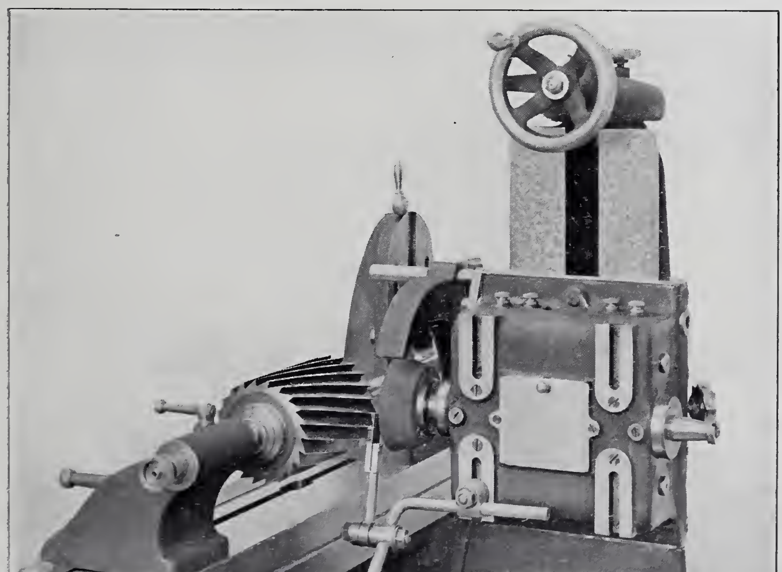


FIG. 3.—SHARPENING A SPIRAL MILLING CUTTER

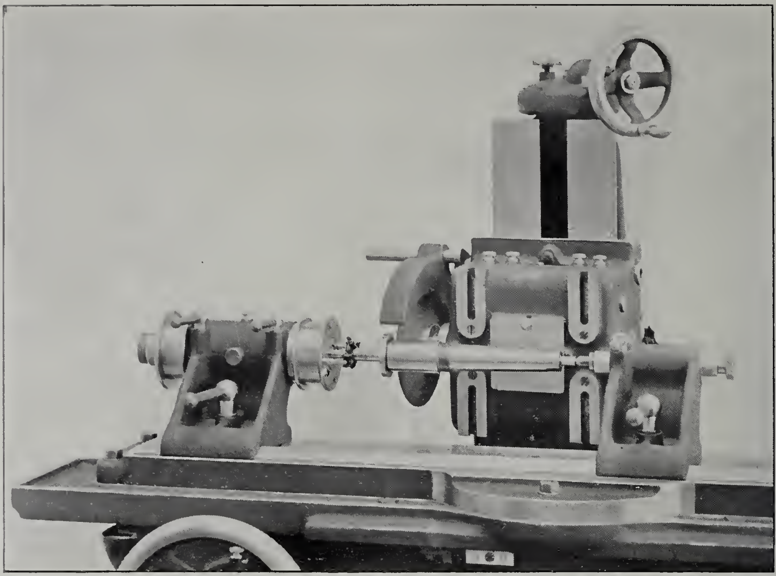


FIG. 4.—GRINDING A SPINDLE

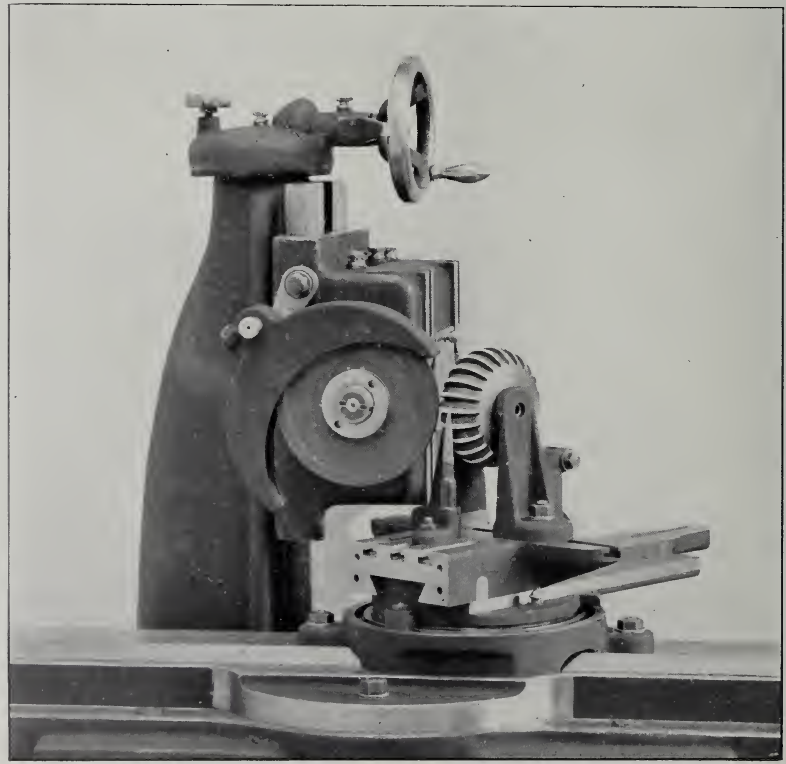


FIG. 5.—GRINDING THE TEETH OF A CONVEX CUTTER WITH A CIRCULAR GRINDING ATTACHMENT

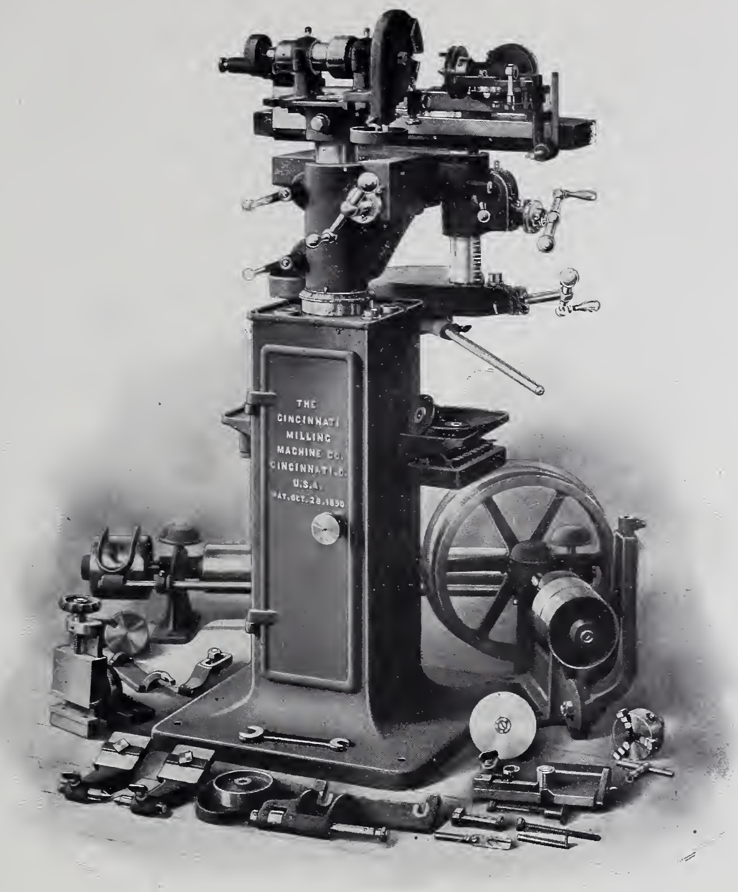


FIG. 6.—UNIVERSAL CUTTER AND TOOL-GRINDER MADE BY THE CINCINNATI MILLING MACHINE CO., CINCINNATI, OHIO

the arc of the teeth immediately above the swiveling centre of the attachment, and then when grinding, the attachment is swung through a sufficient arc to bring the entire periphery of the teeth in contact with the wheel. In this way the form of the cutter is always maintained. It will be readily seen that this same attachment can be used for sharpening the multitude of other forming cutters that have arcs of circles for part of their outline. A very common case of the use of this attachment is in grinding end milling cutters that have round corners, the extreme case of which is the spherical end milling cutter.

Fig. 6 shows the No. 1 universal cutter and tool grinder made by the Cincinnati Milling Machine Company. This machine was designed especially to meet the tool room requirements for a convenient and efficient machine for sharpening all classes of milling cutters, reamers, taps, hobs, etc., in the quickest and most accurate manner possible. It is also adapted for grinding small machine parts, and is a very efficient tool for internal, external, and surface grinding, as well as disc grinding. The table and knee may be swiveled through a complete circle about the column, and the table itself may be set at an angle with its slide. It is fitted with a universal head, so that work may be adjusted at any desired angle and in any conceivable position with relation to the emery wheels, the emery wheel head itself being stationary. The table car-

rying the work centres may be adjusted to and from the emery wheel in the usual manner by means of the ball crank shown, and the vertical adjustment is obtained through a worm and worm

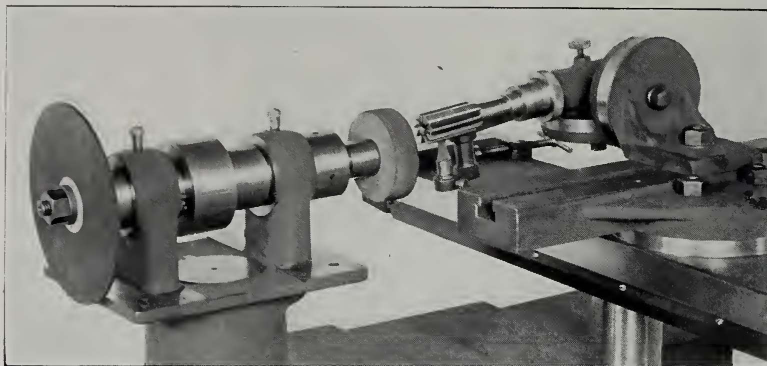


FIG. 7.—SHARPENING THE END TEETH OF AN END MILLING CUTTER

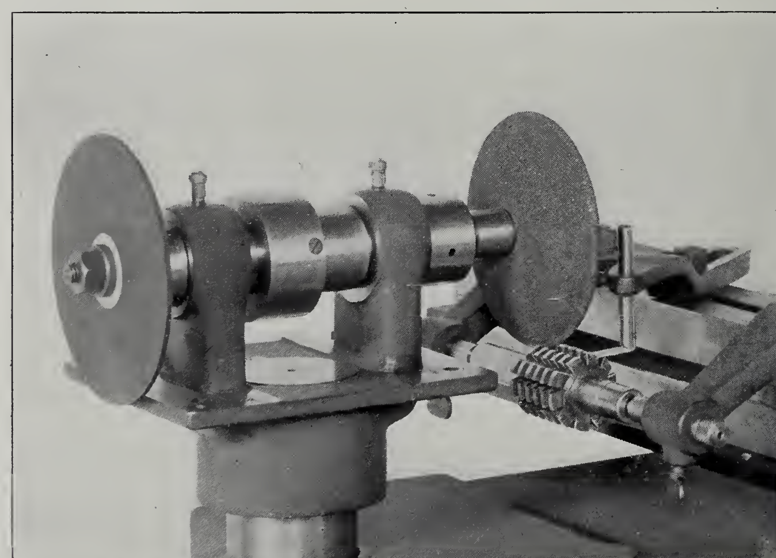


FIG. 8.—SHARPENING A HOB BY GRINDING THE FACES OF THE TEETH

wheel and provided with a micrometer dial.

Fig. 7 shows the manner of sharpening the end teeth of an end milling cutter. In this case the clearance angle is obtained by setting the swivel head to the desired angle of clearance, which may be read direct from the dial provided. The work is held in the spindle of the swiveling headstock, which reduces the chances of its shifting, and, therefore, causing bad work, to a minimum. The method of sharpening a hob by grinding the face of the teeth is shown in Fig. 8, and this suggests that a tap may be sharpened in a similar manner by grinding the faces of its teeth, and thus maintain its form throughout the life of the tap, keeping the faces of the teeth radial, or giving them whatever amount of rake that may have been

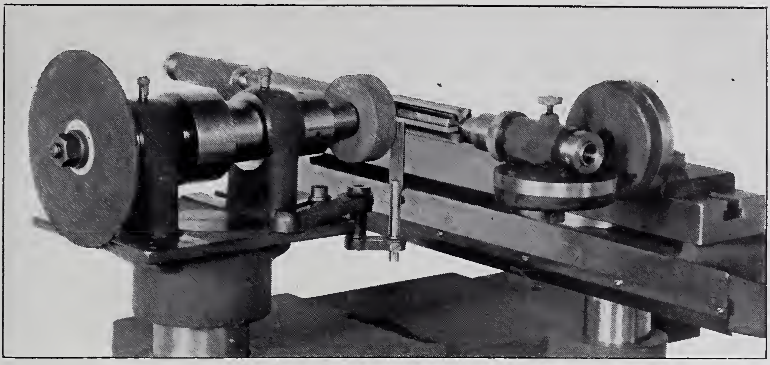


FIG. 9.—SHARPENING A HAND REAMER

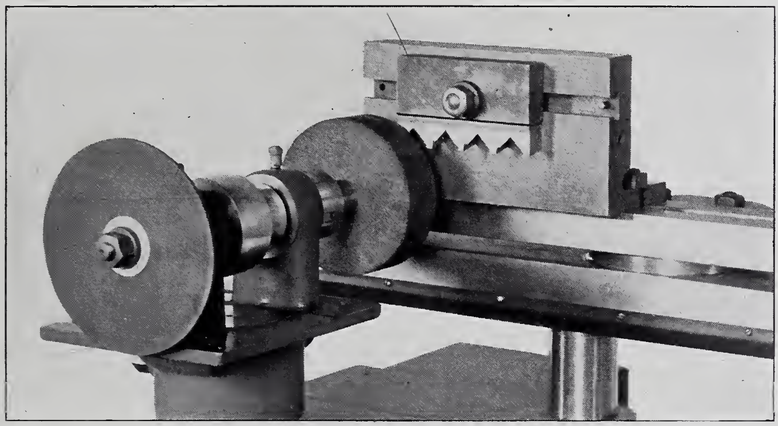


FIG. 10—SHARPENING FLAT-FORMED TOOLS BY GRINDING ACROSS THE FACE

established by custom for the particular work that it is to perform. A tap that is kept sharp in this manner is bound to do a great deal more work during its life and last very much longer than one that is ground occasionally by holding it against an emery wheel by hand, a process which is sure to give a cutting edge that is anything but radial, and the great tendency is to grind only those teeth which have become dull, so that in a short while the form of the tap itself has been spoiled.

Fig. 9 shows the application of the machine for sharpening the teeth of a hand reamer. It will be noted that the work is held between centres, and in this, as in all cutter grinder operations, the work is fed past the cutter by means of the level feed, which permits of very rapid work. A cup-shaped wheel is used for grinding, and the micrometer arrangement for elevating enables the operator to make the vertical adjustment to the exact thousandth of an inch to obtain the proper clearance at the cutting edges. Fig. 10 shows its application for sharpening flat-formed tools for automatic hub machines, by grinding across the face, so that their form is maintained throughout the life of the tool.

A new machine brought out by the Norton Emery Wheel Company, of Worcester, Mass., is shown in Fig. 11. This machine is intended for sharpening all sorts of milling cutters, and is also intended to do general grinding on small machine parts, it being arranged for cylindrical grinding, and also fitted with

attachments for doing internal and surface grinding. It has a capacity of 36 inches between centres, and will swing work 10 inches in diameter. The carriage has an automatic longitudinal movement of 12 inches, cross movement of 9 inches, with a vertical adjustment of 7½ inches. It will sharpen face milling cutters up to 14 inches diameter, 3 inches face, and weighs approximately 2500 pounds. An idea of the general class of work for which it is adapted will be seen from Fig. 12 and Fig. 13. The method which this grinder employs r holding milling cutters and adjusting the same for grinding operations is clearly shown in Figs. 14 and 15, which illustrate the operation of sharpening the teeth of a face milling cutter 8 inches in diameter and with a 2-inch face. In changing from the operation of sharpening the face teeth in Fig. 14 to that of sharpening the peripheral teeth with a cup-shaped wheel in Fig. 15, there is practically no alteration in the relative positions of the cutter and emery wheel spindle, except that in Fig. 15 the axis of the cutter is horizontal and a cup-shaped wheel is used in place of a disc wheel.

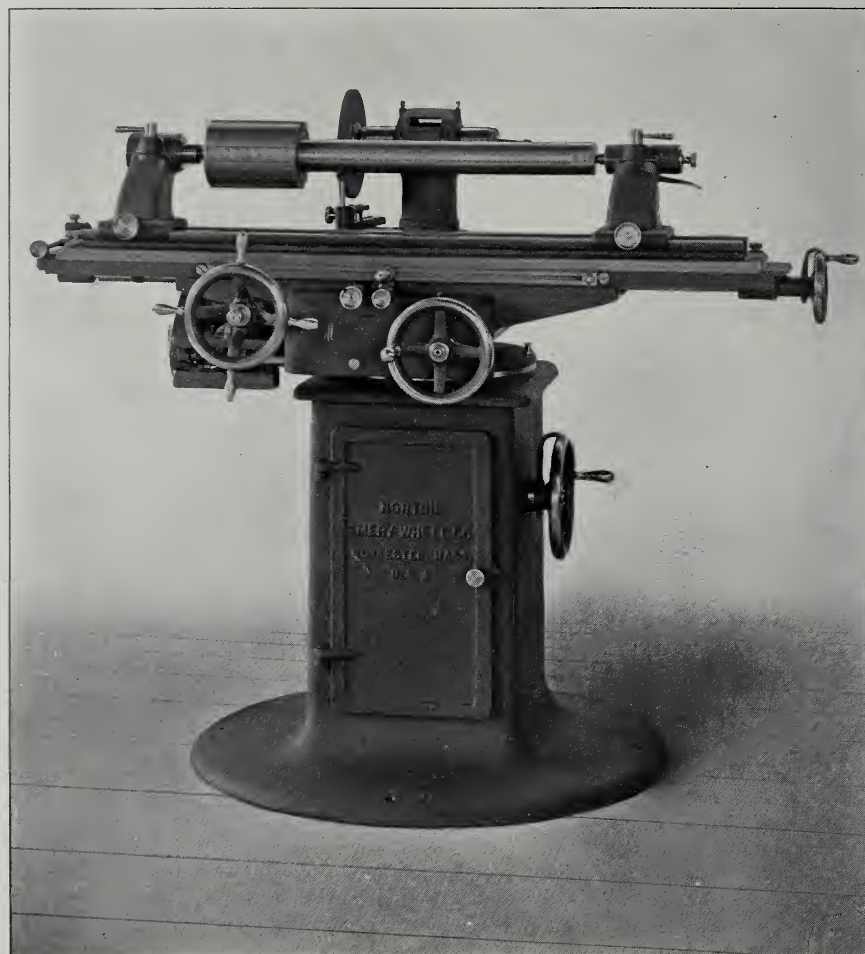
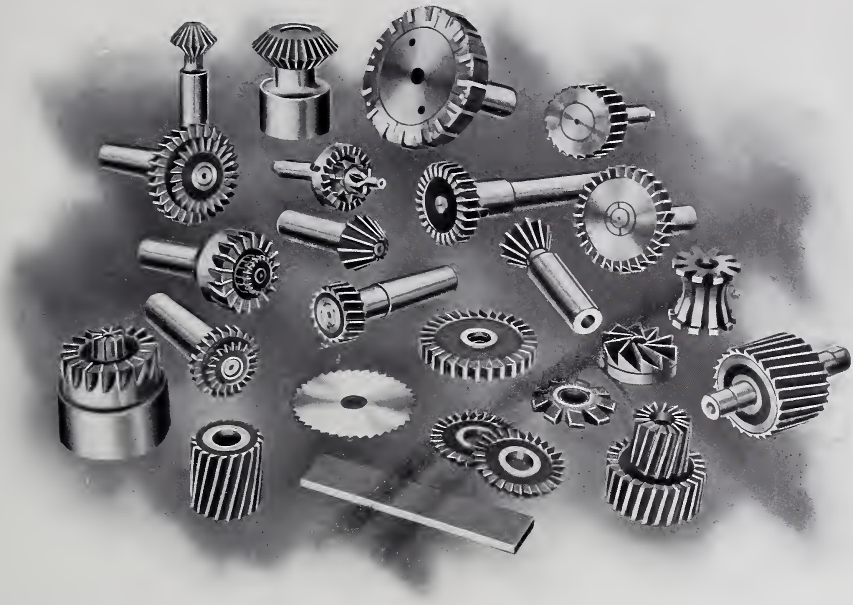
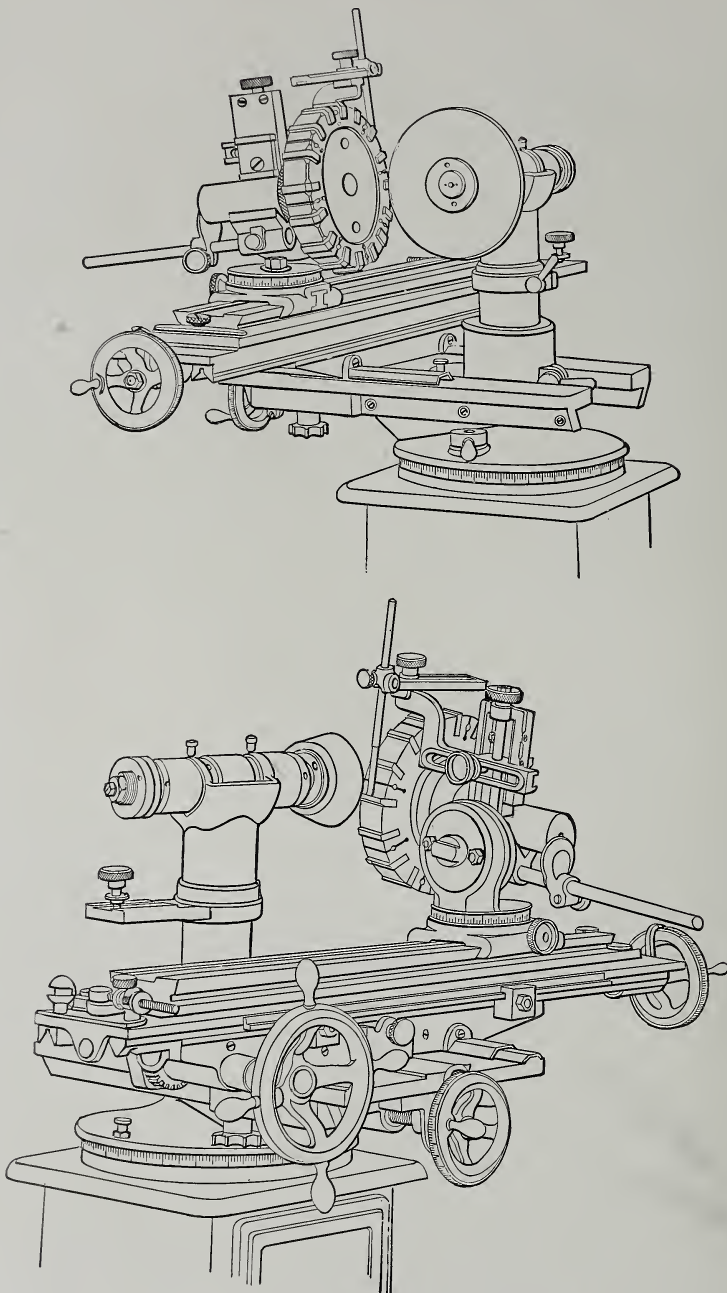


FIG. 11.—NEW GRINDING MACHINE MADE BY THE NORTON EMERY WHEEL CO., WORCESTER, MASS.

In Fig. 16 is shown a new machine



FIGS. 12 AND 13—SPECIMENS OF WORK DONE ON THE NORTON MACHINE SHOWN IN FIG. 11



FIGS. 14 AND 15.—SHARPENING MILLING CUTTER TEETH IN THE NORTON MACHINE

just brought out by the Cincinnati Milling Machine Company. This machine is arranged with direct-connected electric motors for driving the emery wheel spindle and also for revolving the work centres, when the machine is used for cylindrical, internal, or disc grinding, thus entirely eliminating overhead works and belts. It is adapted for doing the same general class of grinding on mill-

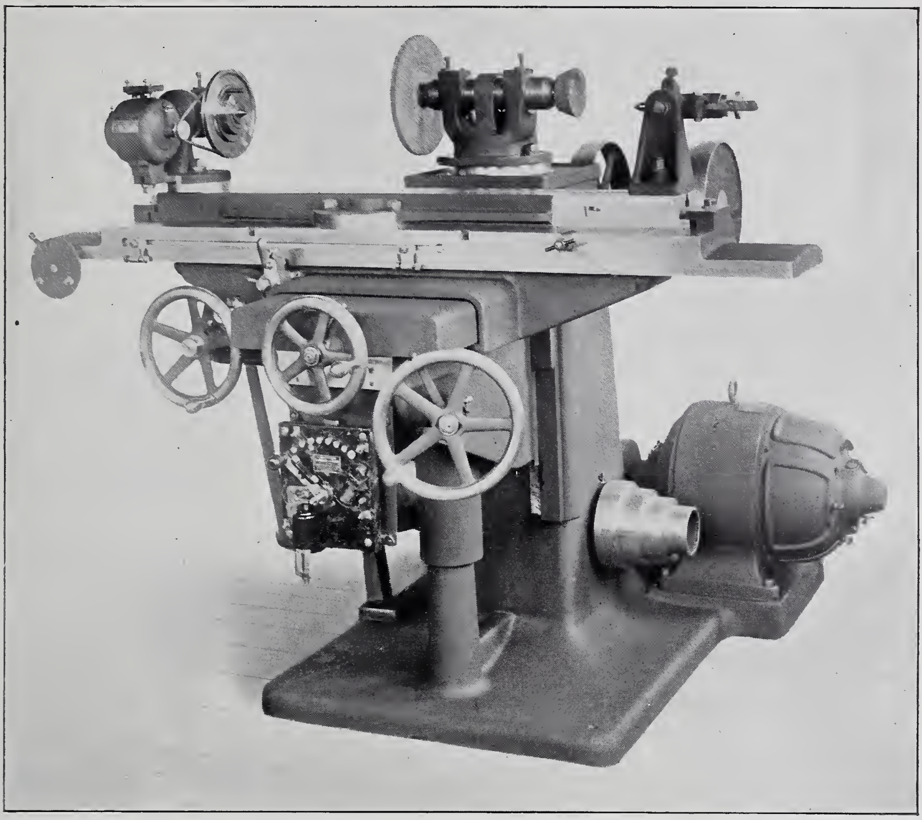


FIG. 16.—THE LATEST GRINDER MADE BY THE CINCINNATI MILLING MACHINE CO., CINCINNATI, OHIO. DRIVEN ELECTRICALLY AS SHOWN

ing cutters, reamers, and small machine parts as the smaller machine made by this company shown in Fig. 6, the essential difference between the two machines being that this new one is very much larger, and is intended for sharpening large face milling cutters and the spiral mills of large diameter and long face that are coming into general use on heavy millers. It will, of course, also sharpen small cutters with equal facility, but is made heavy and rigid in all its parts to prevent vibration when doing heavy work.

This machine has a capacity of 36 inches between centres, with an automatic feed of 24 inches, and will swing work 12 inches in diameter. It has a vertical adjustment below the centre of the emery wheel spindle of 12 inches, and will take in face mills and side milling cutters up to 24 inches diameter with 3 inches face, and will grind the three cutting edges of such cutters. It is provided with eight different automatic feeds, giving thirty-two different table travels in all, ranging from 5 to 70 inches per minute. It weighs approximately 2250 pounds.

Figs. 17 and 18 show the convenience with which this machine can be handled when sharpening side milling cutters of large diameter, the cutter shown being 24 inches diameter and having a face of 2½ inches. It will be noticed that for all these operations the cutter is held in the same fixture, and all the sharpening is done with a cup-shaped wheel. The clearance when sharpening the peripheral teeth, as shown in Fig. 18, is obtained by rotating the cutter so as to bring the face of the teeth at a slight

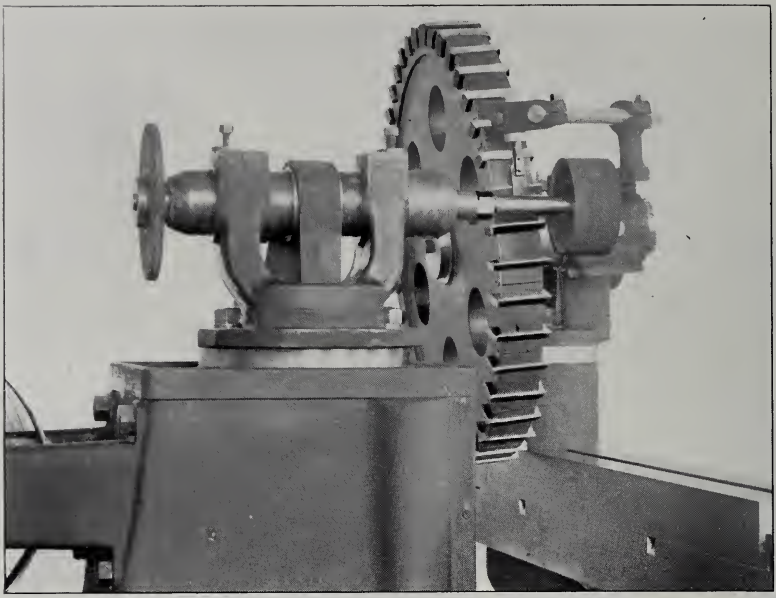


FIG. 17.—SHARPENING SIDE MILLING CUTTERS OF LARGE DIAMETER ON THE CINCINNATI GRINDER

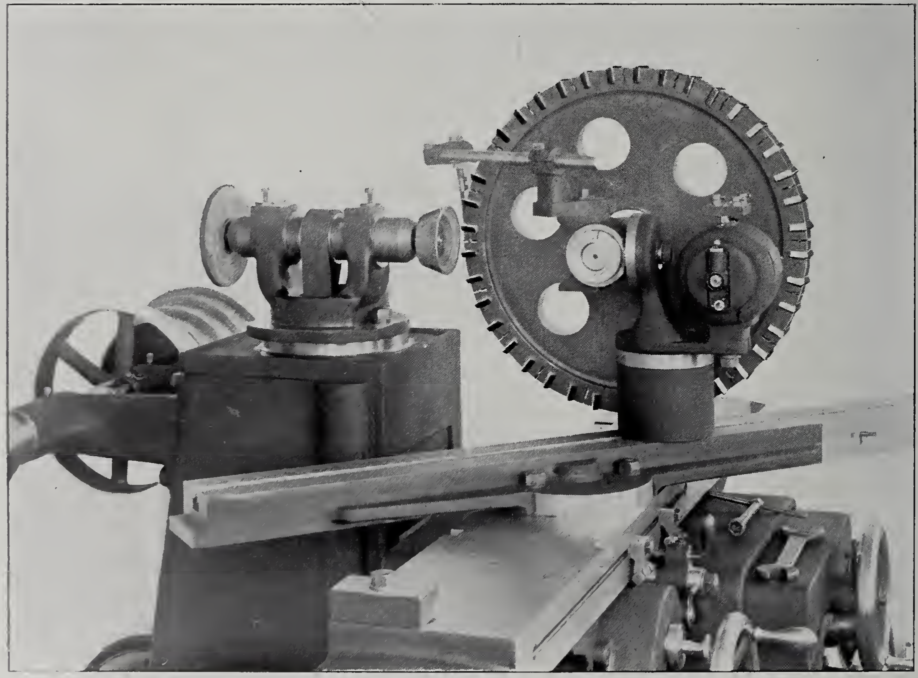


FIG. 18.—SHARPENING THE PERIPHERAL TEETH

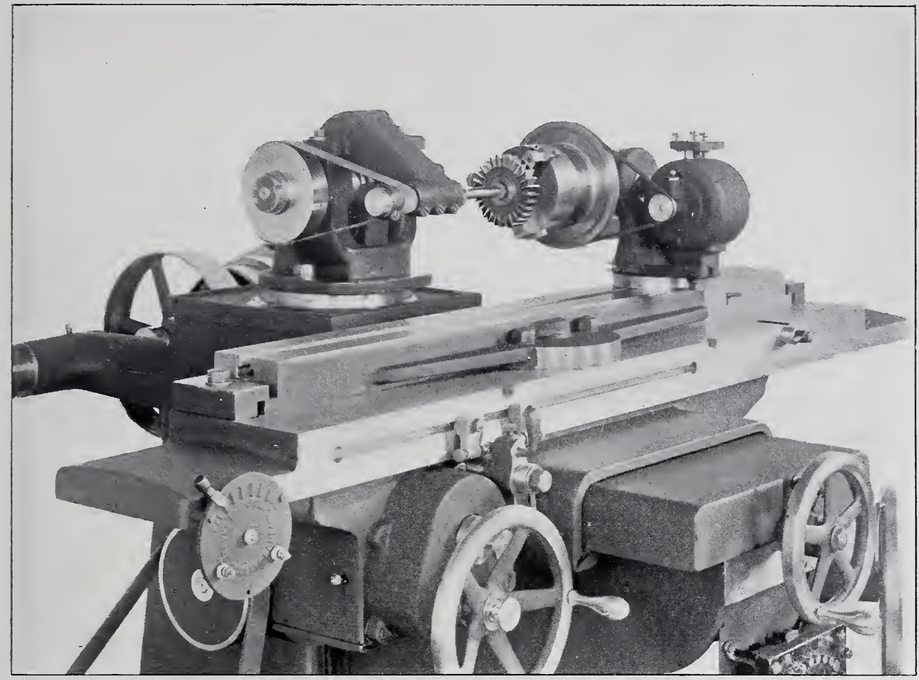


FIG. 19.—A CINCINNATI MACHINE ARRANGED FOR INTERNAL GRINDING

angle (equal to the desired clearance angle) with the axis of the cutter; whereas the clearance angle for sharpening the side teeth, as shown in Fig. 17, is obtained by setting the axis of the cutter at an angle, there being a graduated dial provided from which this angle may be read direct. It is clear, from Fig. 17, that the process of sharpening the teeth on the opposite side is accomplished in exactly the same manner as in this case, except that the emery wheel is held directly on the spindle of the machine without the use of the spindle extension, and the axis of the cutter is set to the corresponding angle above the horizontal position.

Fig. 19 shows the machine arranged for internal grinding. It will be noticed, by comparing Fig. 19 with the previous illustrations, that the angular relation between the main slide of the machine and the emery wheel spindle is obtained on this machine by swiveling the emery wheel head instead of by swiveling the main slide about the column of the machine, which is the course pursued on nearly all grinders of this class.

Fig. 20 is a general view of a new machine just brought out by the Becker-Brainard Milling Machine Company, of Hyde Park, Mass. This machine is designed distinctively as a cutter and reamer grinder; it is capable of grinding heavy cutters of large diameter and long face which are used on the large column and planer type milling machines, also the large diameter inserted tooth cutters. The machine will take care of all styles and sizes of cutters, including plain, straddle, form, and end mills. It is provided with two columns, one of which has a knee with saddle and table, with a 6-inch vertical adjustment, and will swivel around the column in either direction. The adjustable vertical column is graduated so that a setting can be instantly made to give the proper angle of clearance of the cutter for different diameters of emery wheels used.

The table on the saddle is fed by rack and pinion, having a longitudinal feed

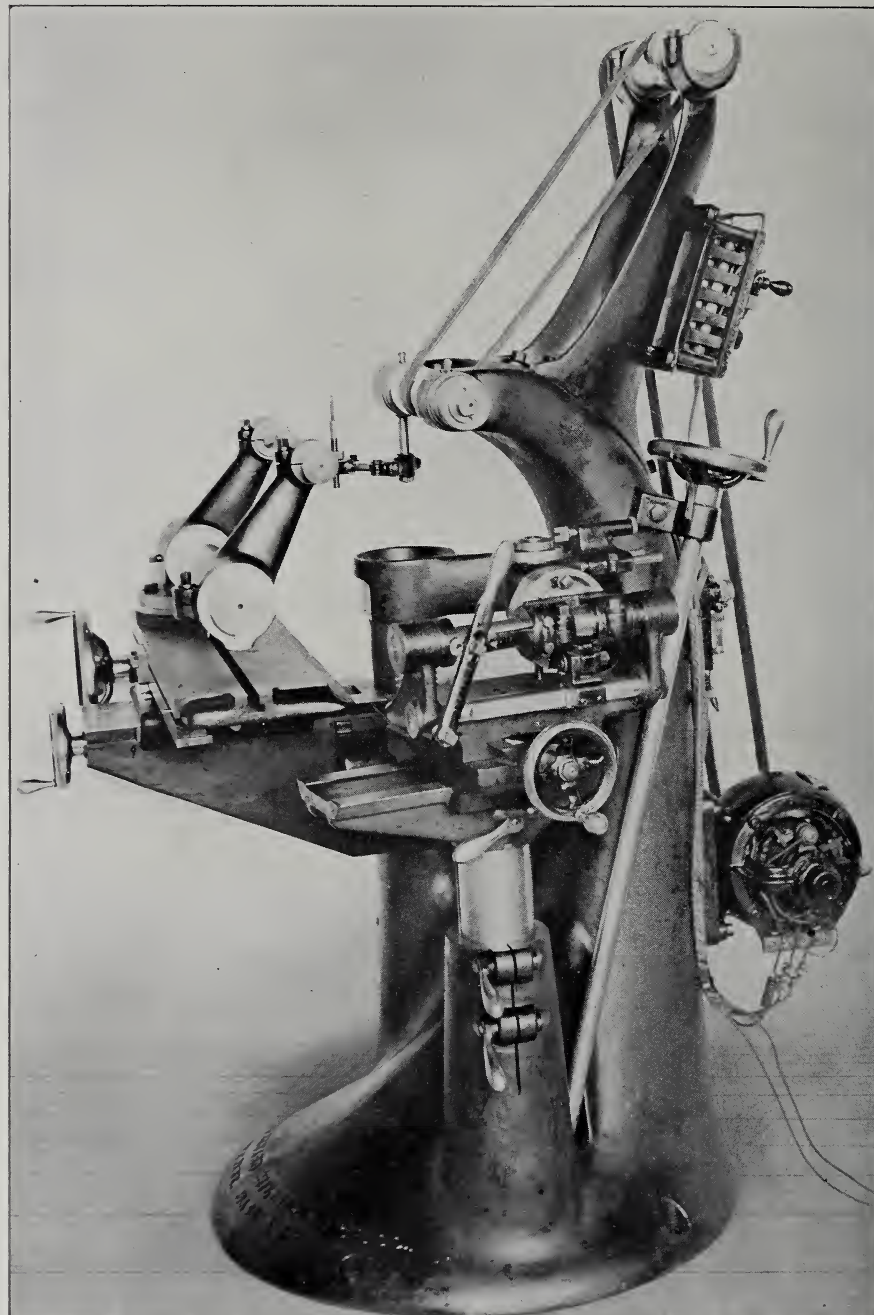
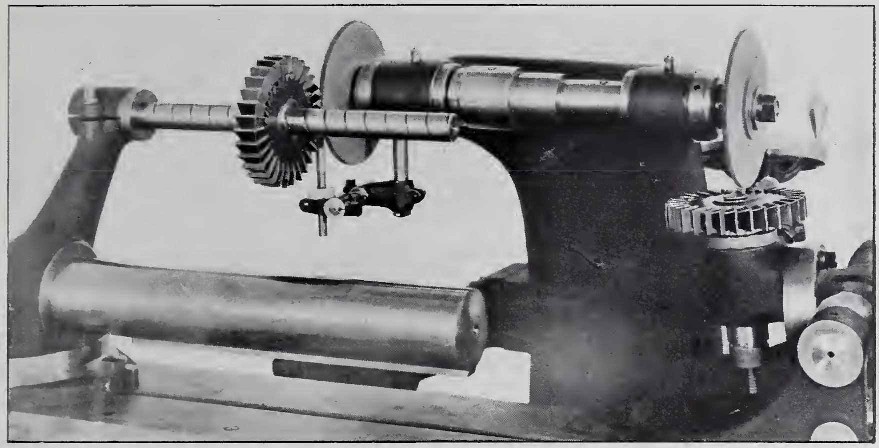
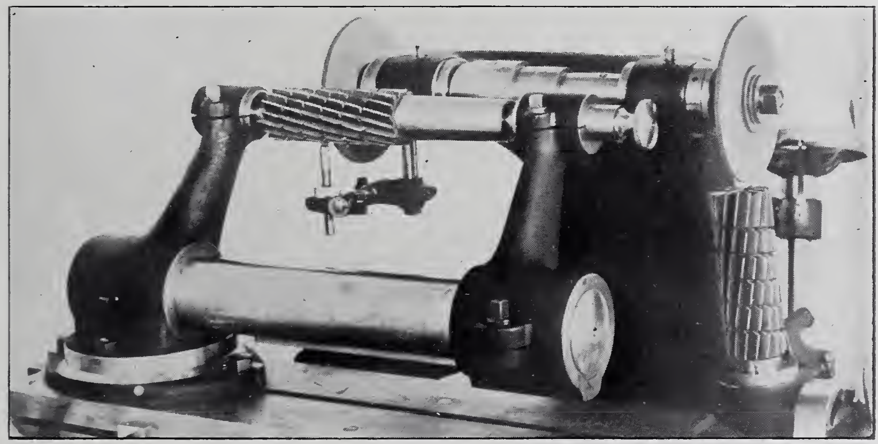
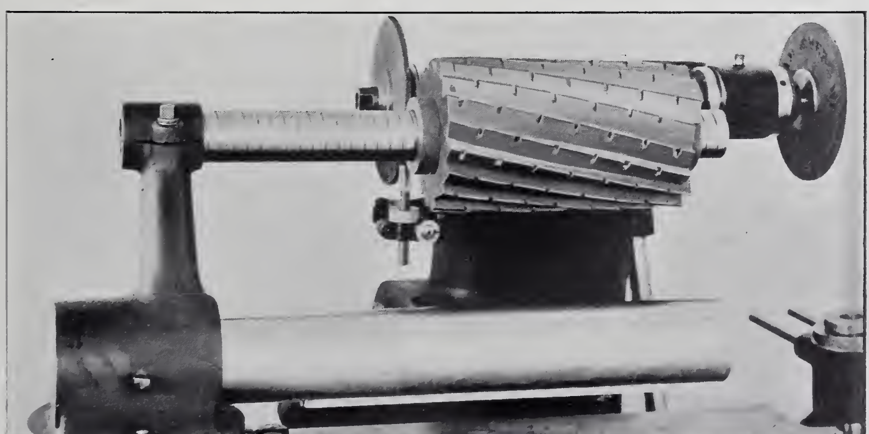


FIG. 20.—NEW CUTTER AND REAMER GRINDING MACHINE MADE BY THE BECKER-BRAINARD MILLING MACHINE CO., HYDE PARK, MASS.







FIGS. 21, 22 AND 23.—METHODS OF HANDLING WORK ON THE BECKER-BRAINARD MACHINE

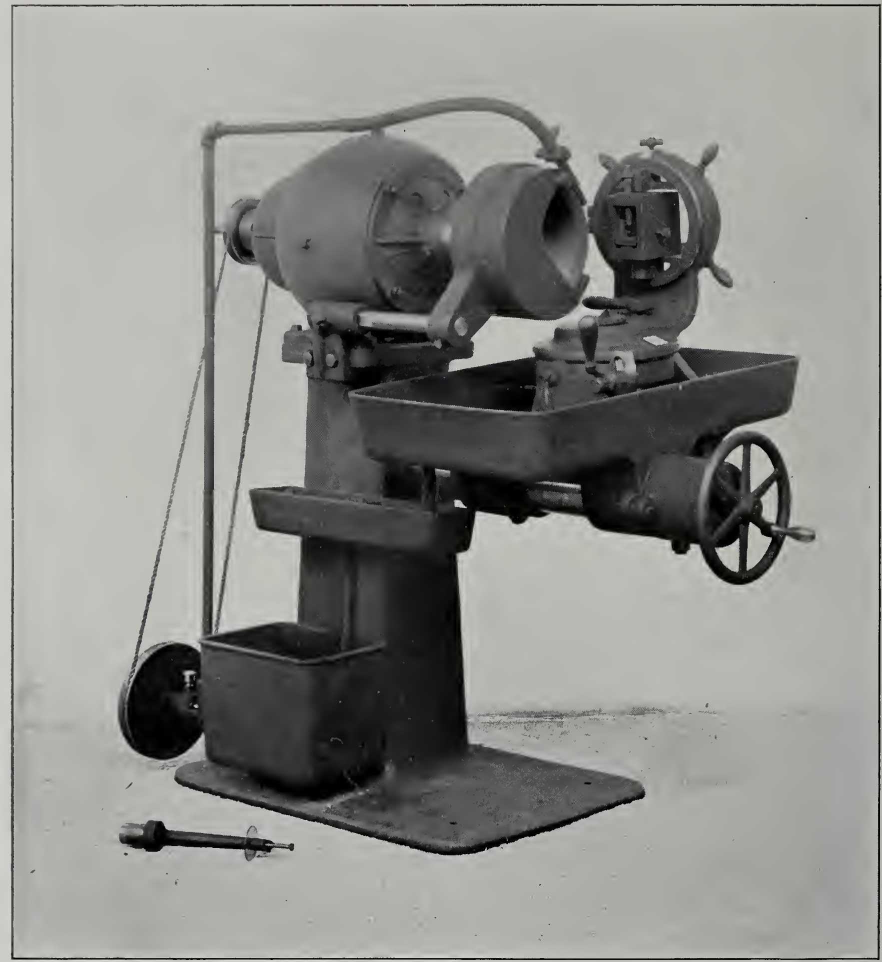


FIG. 24.—AN ELECTRICALLY DRIVEN GRINDER MADE BY THE GISHOLT MACHINE CO., MADISON, WISCONSIN

of 20 inches and a cross feed of 7 inches, and is provided with a graduated swivel head which carries a bar on which to slide cutters while being ground. Head and tail centres are also provided for holding end mills and reamers which have to be ground on centres.

There is a second column, provided with a swivel carriage carrying two cross slides, the top cross slide having 7 inches and the lower cross slide 9 inches adjustment at right angles, to facilitate grinding side, face, and angular mills without employing special fixtures. On the top slide is mounted a graduated swivel head or holder, which slides on a bar having a travel of 5 inches, used for grinding the end teeth of cutters and end mills. Figs. 21 and 22 are good illustrations of the manner of handling work on this machine, showing, as they do, straddle and end mills in both positions. These also show how the clearance is obtained on the end and side teeth.

Fig. 23 shows a large spiral milling cutter in position for grinding. The cutter is held on a steel sleeve, which fits the bar and forms a bearing on which the cutter may be slid back and forth along the bar while being ground. The sleeve protects the hole in the cut-

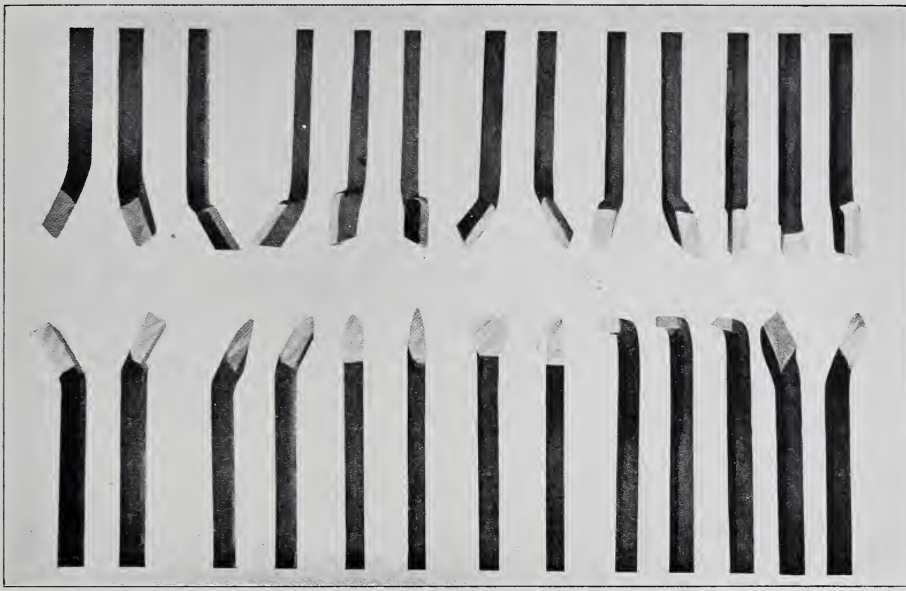


FIG. 25.—THE RANGE OF WORK OF THE GISHOLT GRINDER

ter during grinding. This machine, like the one in Fig. 16, is arranged with a direct-connected electric motor. It will take work 14 inches long by 14 inches diameter between centres, has a longitudinal feed to the table of 20 inches, cross feed of 8 inches, vertical adjustment of 6 inches, and weighs approximately 1570 pounds.

It will be noticed from the illustrations that the machines described are arranged, in most instances, for grinding work by using a cup-shaped wheel, which gives a straight-line clearance with a firm cutting edge. This is generally acknowledged to be the correct method of sharpening milling cutters, reamers, and other tools, as it not only permits of their being sharpened in less time than when a disc wheel is used, but the sharp edges will last longer and have a less tendency to cause trouble on account of chattering than when ground with the periphery of a disc wheel, which grooves the land of the tooth immediately back of the cutting edge. The contrast between the two methods of grinding is particularly marked in the case of sharpening the face teeth of small side milling or end milling cutters, which necessarily have their teeth quite close together. If, on such work, the periphery of a disc wheel is used, the wheel must be very small, so as to not strike the edge of the tooth next to the one being ground, and, therefore, the " land " will be grooved quite deeply and the cutting edges will be very frail. This trouble does not arise when a cup-wheel is used, which is plainly shown in Figs. 17 and 18.

When sharpening cutters, the rotation of the emery wheel should always be such that it will grind against the cutting edge. This prevents it from forming a burr on the cutting edge, and, therefore, gives a smoother and more perfect edge.

In the average shop the most numerous machine tools are lathes, planers, and shapers, and the best shop economy is obtained when the men running these machines are supplied with sharp cutting tools as fast as they are needed, the accepted method being to have in the tool room a machine especially adapted for this class of work and operated by one man whose duty it is to keep the entire shop supplied with tools. In this way the machine tools do not stand

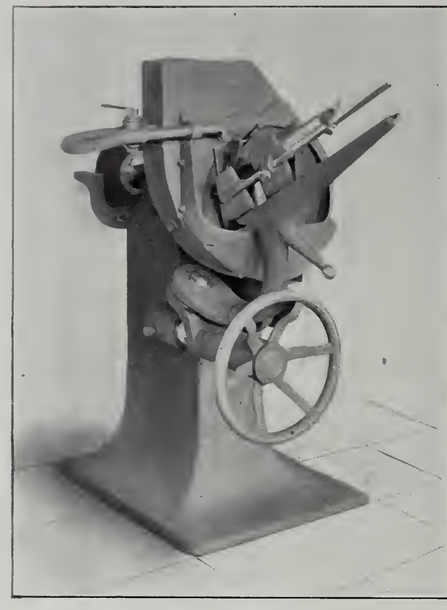


FIG. 26.—A WET DRILL GRINDER MADE BY THE WASHBURN SHOPS OF THE WORCESTER POLYTECHNIC INSTITUTE, WORCESTER, MASS.

idle while the tools are being ground. A good example of a modern lathe and planer-tool grinder is shown in Fig. 24, which illustrates an electrically driven machine made by the Gisholt Machine Company, of Madison, Wis. This machine is fitted with a motor mounted on the top of the column, and the emery wheel is carried on the armature shaft. It is also provided with a pump, making it a "wet" grinder. It is adapted for grinding any shape of tool at any angle, and when a certain shape of tool has been decided upon for a given class of work that tool can be duplicated indefinitely. Fig. 25 gives some idea of the range of work that this machine will cover.

The universal tool grinding and shaping machine Fig. 28, made by Sellers & Co., Inc., of Philadelphia, will take tools with shanks 2½ inches by 2 inches. It is provided with a pump for wet grinding, and with necessary chucks for sharpening all manner of tools and also the faces of the tools, and a crane for changing the wheel on its spindle. The design of this machine is based on the principle that to grind tool steels by means of cutting wheels the contact between the two should be a line and not a surface. Therefore, if it is desired to grind the plain face of a tool, this grinding must be done by the periphery of the cylindrical surface of the wheel, and the surface to be ground must be moved past the periphery of the wheel in a straight line tangent to its curve. The wheel employed on this machine has two conical grinding surfaces forming a *V* with a 90-degree included angle, which makes it very convenient for grinding the different faces of tools, and also enables small and delicate splining tools to be ground. The tool chuck is arranged so that it can be rotated on a horizontal axis parallel with the tool, and can be set for grinding to any angle, there being a graduated circle

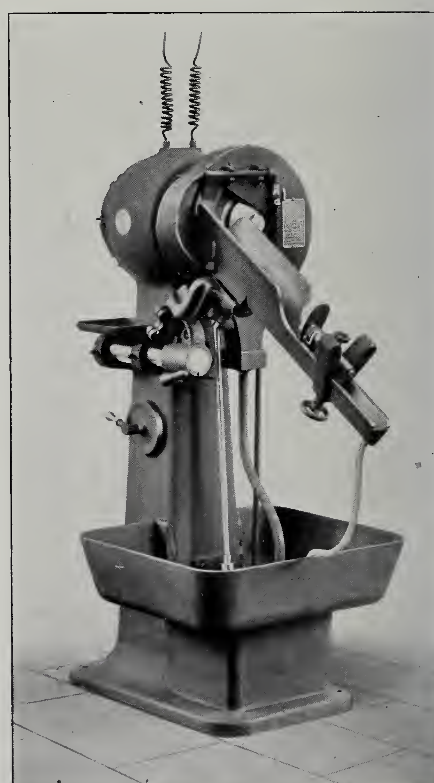


FIG. 27.—ELECTRICALLY DRIVEN GRINDER MADE BY THE WILMARTH & MORMAN CO., GRAND RAPIDS, MICH.

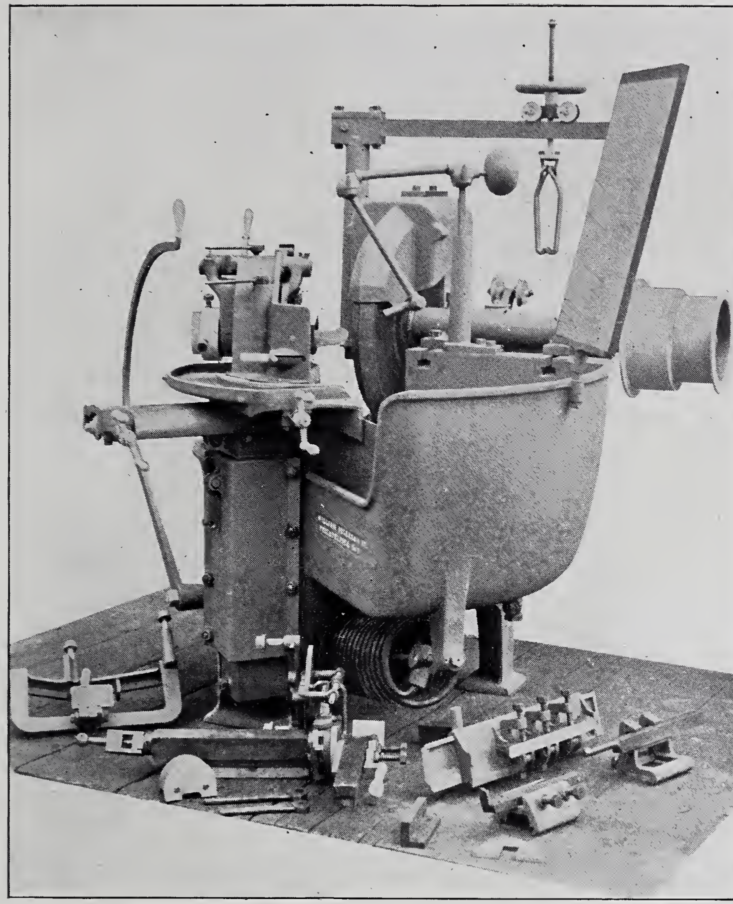


FIG. 28.—UNIVERSAL TOOL GRINDING MACHINE MADE BY WILLIAM SELLERS & CO., INC., PHILADELPHIA

provided, reading to one-tenth of a degree.

Fig. 26 shows the new No. 00 wet drill grinder made by the Washburn shops of the Worcester Polytechnic Institute, of Worcester, Mass. This machine grinds drills ranging between ¾ inch and 4 inches diameter, and will support a drill 4 feet long. The drill holder is so constructed that the drill, irrespective of its diameter or length, is simply laid into the holder and swung against the grinding wheel, no adjustment being necessary.

The most striking feature of this drill grinder is that which causes the water to automatically flood the drill in a continuous stream without the use of a pump with its troublesome stuffing boxes and complicated connections. The water, when picked up by the grinding wheel as above described, is thrown by centrifugal force into a reservoir from which it is again conducted to the drill.

The drill to be ground is held with its point lower than its shank. This allows the water to be applied to the drill itself, flooding the point, instead of applying it to the wheel in the old way. The advantages of this are apparent. The old way caused the water to acquire the velocity of the rapidly revolving wheel, consequently when the drill was brought in contact with it, the water re-

fused to stop, but simply changed its direction, much to the discomfiture of the operator. By applying the water first to the inverted drill, it gets only the velocity acquired in falling. The drill holder causes it to back up about the point of the drill, at times actually submerging the parts which are being ground. The spindle of this machine has double bearings, self-oiling journals with compensation for wear, and a special device for accurately controlling all lateral motion of the wheel.

Fig. 27 shows an electrically driven "Yankee" drill grinder, made by the Wilmarth & Morman Co., of Grand Rapids, Mich. The emery wheel is mounted directly on the motor shaft, eliminating the use of a belt, and the starting box is built into the column of the machine, making the entire construction self-contained. The machine is arranged to provide for the greatest possible convenience when grinding drills of different diameters, the makers claiming, quite correctly, that "most men have an antipathy to making a lot of adjustments, and would rather hold a drill up to the wheel by hand than go to much trouble adjusting the machine."

One of the important features of the machine is based on the fact that on a large drill the radius of the curved surface at the point is greater than on a smaller one. The construction of the drill holder and its parts is such that this principle is maintained when the machine is adjusted for different clearances.

This adjustment for clearance is made by rocking the drill holder proper in its seat, the axis of this motion being the apex of the *V*-groove. This action, say when adjusting for more clearance, throws the upper part of the *V*-groove more to the right than the lower part, and since the larger drills occupy the upper part of the *V*-groove, they are ground with a larger radius, but with the same proportion of clearance as the smaller ones. From this it will be clear that with a single setting of the machine all sizes of drills within its range will be ground with the proper radius at the point, varying for each size of drill, and all will have the same proportion of clearance.

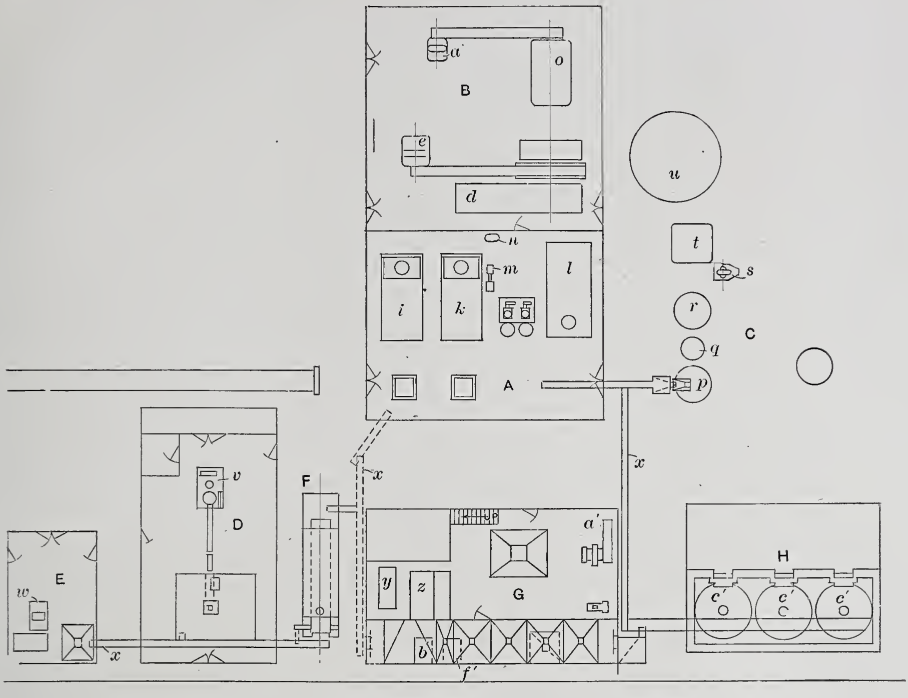
A COAL-TESTING PLANT AT THE ST. LOUIS EXPOSITION

By D. T. Randall

WHILE making arrangements for the exhibits of mining industries for the St. Louis Exposition, Prof. J. A. Holmes, chief of the Mines and Metallurgy Department of the Exposition, and Mr. E. W. Parker, statistician of the United States Geological Survey, perceived the need of reliable records of the coals of the United States and also the desirability of conducting experiments to determine the most economical ways to utilise them. Through their efforts this was brought to the attention of the United States Congress, and an appropriation of $60,000 was secured. But this appropriation contains the clause,—"All testing machinery and all coals and lignites to be tested shall be furnished to the government free of charge."

It has been ruled by the Comptroller of the Currency that, under the provision, not even the freight on the equipment or coals may be paid by the government. This has resulted in much delay; but manufacturers of the necessary machinery and the railroads, realising the importance of the work, have together furnished and delivered practically all the necessary equipment, and the mine operators and the railroads have agreed to furnish the coals to be tested, without charge.

The committee appointed by the di-



PLAN OF THE ST. LOUIS COAL TESTING PLANT

rector of the United States Geological Survey to conduct these investigations is composed of Mr. E. W. Parker, Prof. J. A. Holmes and Mr. M. R. Campbell, geologist. This is the first attempt of the American Government to make a study of American coals. These tests will be conducted primarily to determine the properties of the coals and the most economical methods of utilising them. This will also incidentally bring out the relative values of the different coals. It is hoped that a sufficient number of coals may be tested under this appropriation to show the value of the investigations, and that provision may be made to enable the committee to continue the work until all coal fields of importance have been tested.

The coal-testing plant which has been erected is located in the Mining Gulch on the St. Louis Exposition grounds, at St. Louis. The arrangement of the buildings and machinery is shown on the plan on this page. The investigations are to be divided under the following seven divisions:—

1.—A Geological Field Force.

2.—A Chemical Laboratory.

3.—A Crushing and Washing Plant (*G*).

4.—Two Briquetting Plants (*E* and *D*).

5.—A Gas Producer and Gas Engine Plant (*C*).

6.—A Coke Oven Plant (*H*).

7.—A Steam Boiler and Engine Plant (*A*).

The plans of operation are as follows:—Coals from all parts of the United States will be sampled and shipped to the plant for testing.

One or more complete chemical analyses of the coal from each car will be made.

All coals will be crushed to a suitable size.

The fine coals will be washed if they contain a large quantity of impurities.

The lignites and washed coals will be

dried in a rotary dryer before being delivered to the briquetting plants.

The fine coal from nearly all shipments will be made into briquettes and tested to determine the suitability of the binding materials.

Many of the coals will be tested in a gas producer to determine their suitability for this purpose. The gas will be used in a gas engine and the power will be measured.

Coals suitable for making coke will be tested in coke ovens.

All the coals will be tested in boiler furnaces and the steam used in a steam engine. Records of power developed will be carefully made.

One of the first and most important considerations in making such investigations is to determine that the coal sent for testing is a true sample of the coal as usually shipped from the mine, and not a sample much better than the average, selected especially for testing. Coal for these tests will be shipped from the mines in sealed cars, under the supervision of Mr. M. R. Campbell or one of his assistants, who will see that the car is loaded with the usual run-of-mine coal. A sample will also be selected at the mine by cutting a groove from the top to the bottom of the seam and collecting the cuttings, which will be mixed and quartered down to one quart. This sample will be sent direct to the Chemical Laboratory for analysis. It is expected by this means to show what reliance may be placed in the usual method of taking samples.

The Chemical Laboratory is located in the "Metal Pavilion," and is in charge of Prof. N. W. Lord, of the Ohio University. Analyses of the coals will be made, not only as delivered in the cars, but also as furnished to each department. As the coal from the same car may be tested for from two to four purposes, according to its composition, it will be necessary that five or six chemical analyses be made of the coal in each car. These determinations will be made very carefully as to the composition and the heating value of the coals. A Mahler bomb calorimeter has been placed in a constant temperature chamber for the purpose of determining the number of heat units in the coals.

The coal will be delivered in the Washery Building and fed into a crusher *f* made by the Link Belt Machine Company, of Chicago. This will reduce it to one and one-half inches or smaller. It will then be elevated to a half-inch revolving screen, in which the fine coal will be separated. The larger coal will be delivered to the other departments as desired by conveyors *x* made by Robbins Conveying Belt Company, of New York City. The elevating machinery will be arranged to divert a portion of the coal to a bin for a sample.

The fine coal will be washed if it contains a large percentage of impurities, such as slate, sulphur and earthy matter. For this purpose two jigs, *y* and *z*, have been provided. There is also a pulveriser *b'*, made by the Williams Pulveriser Company, of Chicago, for further reducing the coal to be briquetted. A 50 horse-power engine *a*, furnished by the Frost Manufacturing Company, will operate the machinery in the Washery Building. A large rotary dryer *F* has been installed by the C. O. Bartlett & Snow Company, of Cleveland, Ohio, for removing the moisture from lignites and washed coal intended for briquetting.

The coal delivered to each department will be weighed and the resulting product accounted for either as power or material, in order that conclusions may be reached regarding the best methods of using the coals.

William Johnson & Sons, of Leeds, England, have furnished a large briquetting machine *v*, which has been successful in England. This machine is fed from a series of disintegrators, mixers, and elevators. The machine automatically charges the moulds with the mixture, compresses it between two powerful plungers, and discharges the briquettes upon a conveyor. It has a capacity of fifty tons of briquettes per day.

The other briquetting plant is equipped with a double roller machine *w* which forms the mixture into cakes similar in size and shape to the ordinary cake of toilet soap. This machine, also

of a capacity of fifty tons per day, was installed by the American Compressed Fuel Company, of Chicago.

Commercially successful briquetting plants are very rare in the United States, owing to the difficulty in finding a suitable binding material at a low cost. At the Exposition plants, various materials will be experimented with, such as pitch, tar, sugar house refuse, flour, and others, and the resulting briquettes will be tested for hardness and fuel value. It is hoped that the experiments may result in putting this method of utilising coal upon a commercial basis in the United States.

Three coke ovens c', of the plain beehive type, will be used to test the coal to determine if it will make coke suitable for foundry use. The resulting product will be used in the model foundry, which is located near the testing plant. A sample will also be sent to the Chemical Laboratory for analysis. This plant will be operated under the direction of Mr. F. Stammler, of Johnstown, Pa.

Messrs. R. D. Wood & Co., of Philadelphia, have furnished a 300-H. P. Taylor gas producer p, complete with economiser q, scrubber r, centrifugal extractor s, purifier t, and a gas holder u of 5000 cubic feet capacity. This producer will furnish gas to run a 280-H. P., three-cylinder, vertical gas engine o, furnished by the Westinghouse Machine Company, of Pittsburg, Pa. This plant will be operated with all of the coals sent to be tested, including the bituminous coals and lignites. The makers are confident that it will work successfully, and visitors are showing a good deal of interest in it, as there are at present very few plants working on soft coal. The difficulty in operating such plants has been due to imperfect methods of extracting the tar and other impurities.

The gas engine will drive a belted electric generator c', which will furnish current for power. The coal fed to the producer will be weighed, the gas metered and the power generated will be recorded.

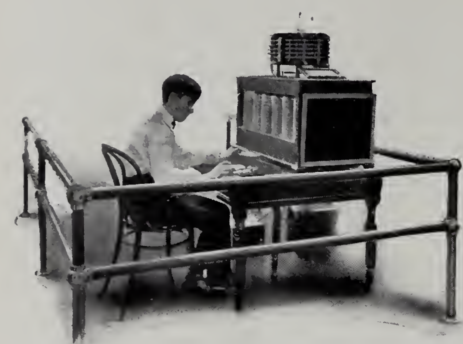
The boiler plant consists of two 210-H. P. Heine boilers i and k, one horizontal tubular boiler l, of 100 H. P. capacity, a feed-water heater n, and a pump m. The horizontal tubular boiler will furnish steam to the washery and other plants in the "Gulch" needing steam. The Heine boilers are equipped with complete apparatus for making boiler tests. Each has a stack 42 inches in diameter and 115 feet in height above the grates, which are of plain, hand-fired type.

Practically all the coals sent for testing will be tried under these boilers in accordance with the code of the American Society of Mechanical Engineers for conducting steam boiler trials. The results of each test will be computed by an office force as soon after each test as complete data can be secured from the observers and the Chemical Department. These tests will be made under the directions of Prof. L. P. Breckenridge, of the University of Illinois. The steam generated by the boiler being tested will be used in a 250-H. P. Allis-Chalmers Corliss engine d', driving a Bullock generator e'. A record of the coal used and the power generated will be kept. The Westinghouse Electric & Manufacturing Company, of Pittsburgh, are furnishing the motors for driving the machinery of the various plants from power developed in the engine room.

The government has expended a large sum in erecting the buildings and machinery, and the operating expenses for conducting the tests will probably exhaust the balance of the appropriation before all the work contemplated can be accomplished.

WIRELESS TELEGRAPHY AT THE ST. LOUIS EXPOSITION

By Cloyd Marshall



SENDING WIRELESS TELEGRAPH MESSAGES FROM THE PALACE OF ELECTRICITY

THE highest structures on the St. Louis Exposition grounds are the long-distance wireless telegraph stations. The Observation Tower, built of steel and 300 feet in height, is covered with 3500 incandescent lamps, which makes it particularly conspicuous at night. The tower was erected primarily as a wireless station by the De Forest Wireless Telegraph Company, but as it has several very large platforms, it was eminently fitted as a point of observation for the whole Exposition.

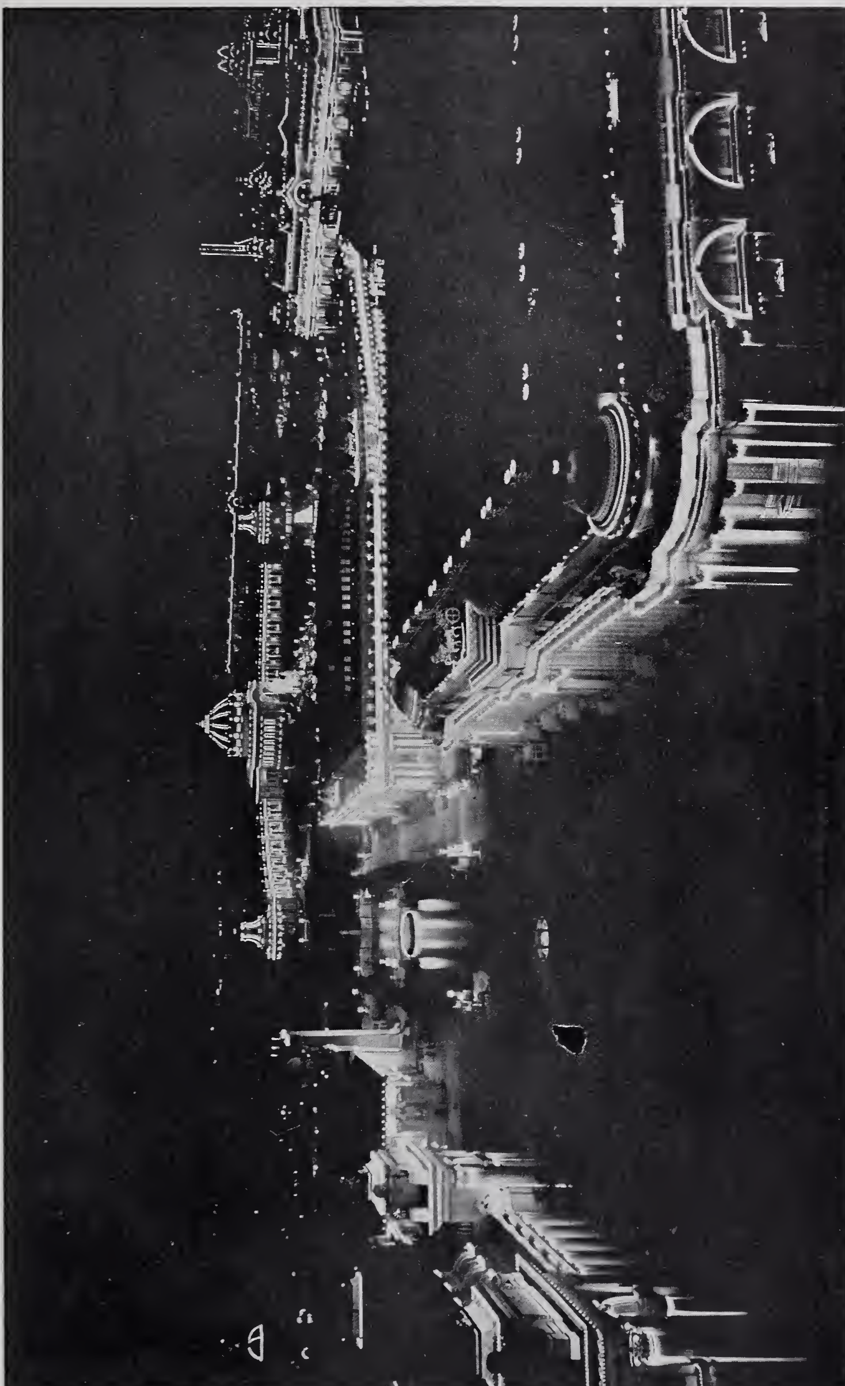
Two electric passenger elevators carry visitors to the wireless telegraph station on the 100-foot platform and to the platforms at the top. The view from this point of the city and Exposition grounds is unsurpassed. One would not do justice to the Fair if, in speaking of this wireless telegraph tower, mention were not made of the unsurpassed beauty of the panorama of the illumination, seen at night from its lofty balconies.

As fascinating as is the day scene, the spectacle of Festival Hall, the circle of the Terrace of States, the fan-shaped grouping of the exhibit palaces, combines to form a picture surpassing any which man's eye has ever beheld. After all the other lights upon the Exposition buildings are extinguished, this slender beacon tower, with its ring of lights clustered around the peak of its flagstaff, shows to all for many miles around where the Ivory City is located. But its other rays, non-luminous and unknown by any human sense, are carried many times further than any illumination can reach,—the new radiation by which the wireless messages are transmitted.

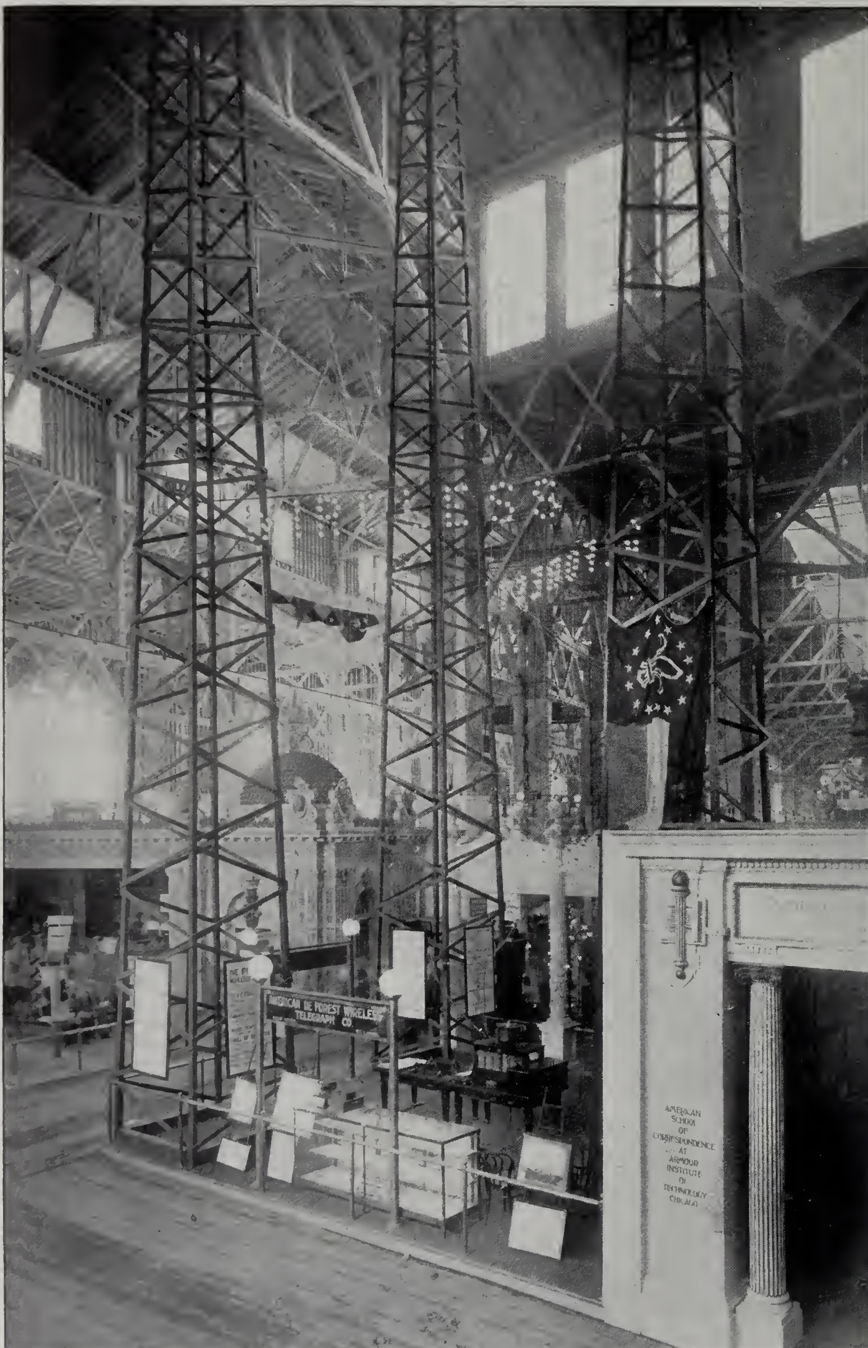
The wireless telegraph station itself is located on the platform 100 feet above the ground, all the instruments being housed in a glass enclosure. Connected to this are the antennæ wires leading up to a gaff extending from the roof of the tower, a distance of 200 feet. Two newspapers, the St. Louis *Post-Dispatch* and St. Louis *Star*, receive regular daily news service from this station. About 5000 words of copy per day are transmitted at a rate of 25 to 35 words per minute, detailing such World's Fair news as the newspapers' representatives can collect upon the grounds. The downtown operators are located in the press rooms of the newspapers, and hand the copy from the wireless receiving station directly over to the typesetter. Notwithstanding the fact that the steel structure of this tower makes it not at all well suited for wireless telegraph transmission, yet messages have been received from this station as far as the city of Springfield, at an air line distance of 105 miles, entirely over land.*

The power supply at the tower is 500

*Since this was written wireless telegraph messages have been sent from the De Forest long-distance tower to Chicago, 300 miles away.—THE EDITOR.



A NIGHT VIEW FROM THE AMERICAN DE FOREST WIRELESS TELEGRAPH OBSERVATION TOWER.



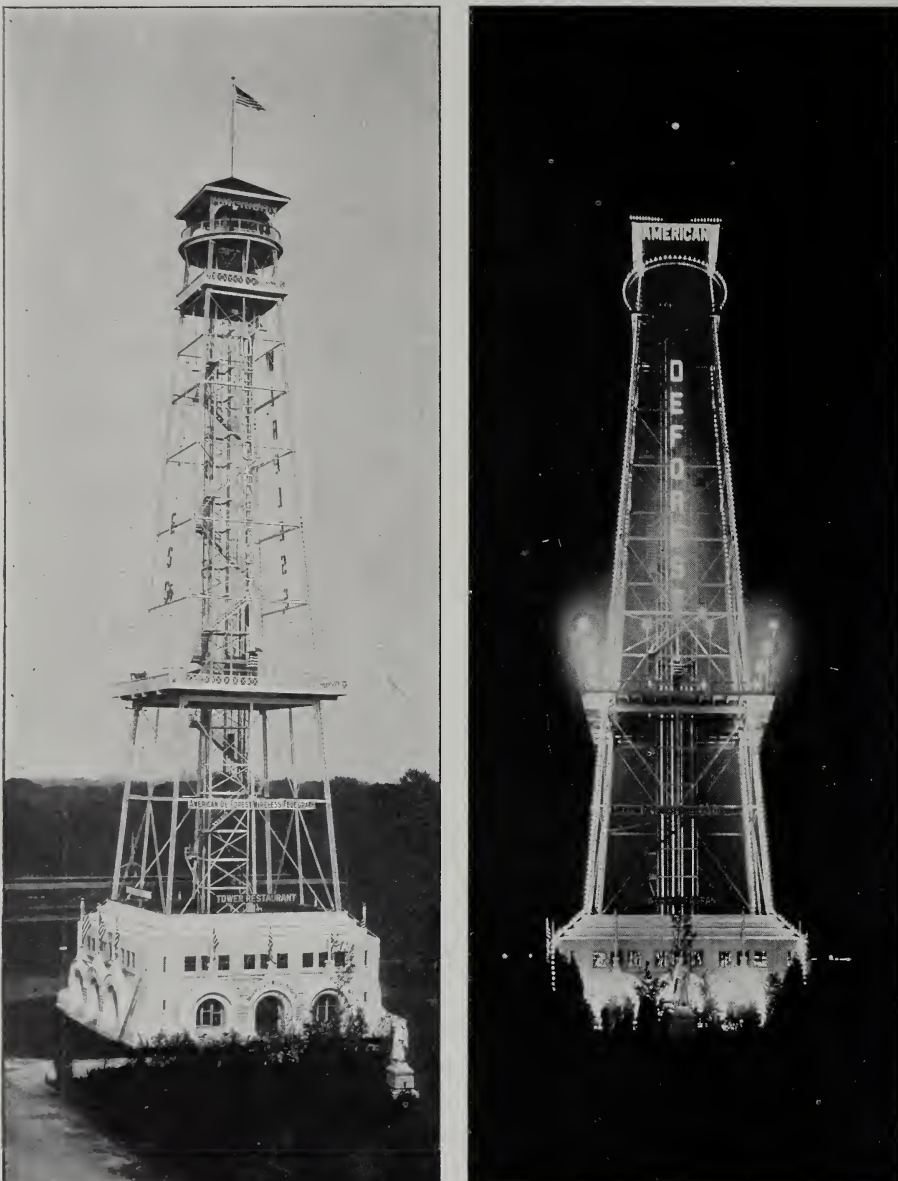
THREE DE FOREST WIRELESS TELEGRAPH TOWERS INSIDE THE ELECTRICITY BUILDING

THE DE FOREST LONG DISTANCE STATION ON ART HILL. THE MAST IS 210 FEET HIGH

volts direct-current. A 70 horse-power motor-generator transforms this to 240 volts direct-current, which is supplied to the elevator motors. On the 100-foot platform a 240 volt motor drives by belt a 2-KW, 60 cycle, 110-volt generator. This voltage is used for the wireless telegraph transmitter. The speed with which the ordinary Morse key of the transmitter can cut up this 60-cycle current into the dots and dashes of the telegraph code is astonishing. A speed of transmission fully equal to any attained on land wire is maintained at this wireless station.

In addition to the observation tower the De Forest Company has a long-distance station on Art Hill, three stations in the Government Building, two in the Palace of Electricity, and two wireless telegraph automobiles. In the southwest corner of the Electricity Building is the principal exhibit of the De Forest Company. Here stand the tallest structures in the building, the only wireless telegraph towers, in fact, ever erected inside a building. Three slender, graceful towers of wood reach aloft 75 feet to the very eaves of the building, representing, in fac simile, the 225-foot towers which the American De Forest Company is about to erect on Cape Flattery, Washington, for Alaskan and trans-Pacific service.

From the tops of these three towers depend three screens of fine antennæ wires, converging at the bottom to the helix on top of the transmitting instrument. All day long the operators at this booth are busy transmitting and

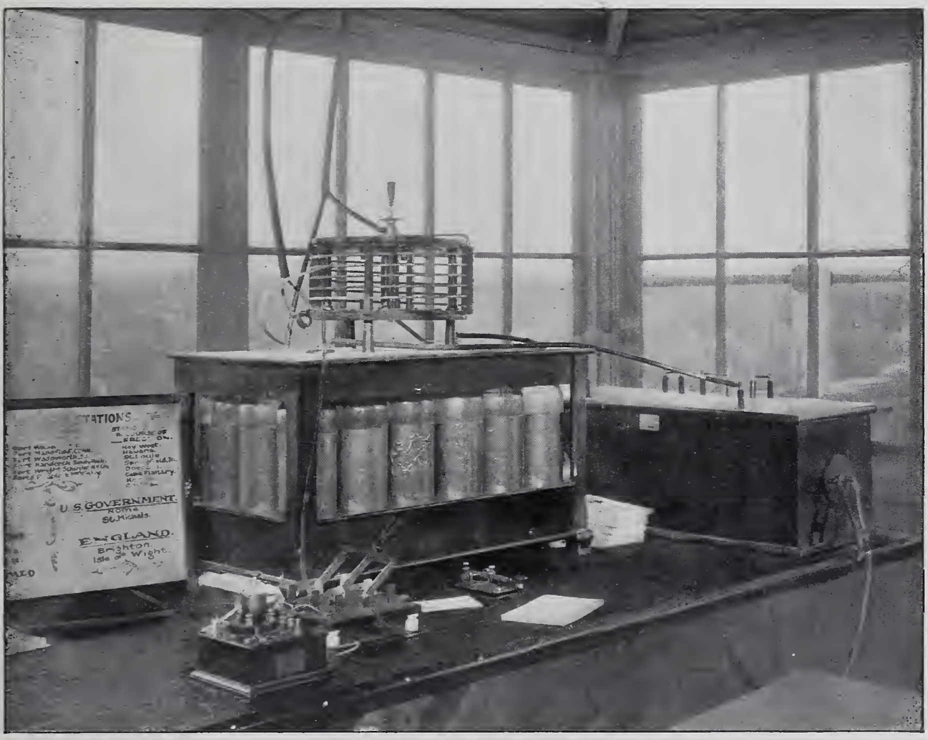


DAY AND NIGHT VIEWS OF THE DE FOREST WIRELESS TELEGRAPH OBSERVATION TOWER, NEARLY 300 FEET HIGH. THE WIRELESS STATION IS ON THE 100-FOOT PLATFORM

receiving messages from the tower of the long-distance station, or from the Fort Wayne station, in the same building. A most popular test to the public is to write out messages at the station in the Fort Wayne exhibit, and, strolling over to the main De Forest booth, find them already copied by the operator there. The illustration on page 594 shows the operator at the Fort Wayne station sending a message to the tower.

The power supply for sending messages is 60-cycle alternating current from the Machinery Building, from which 110-volt current is used for the wireless telegraph transmitter. A 2 KW transformer raises the potential to 20,000 volts, the secondary being connected to 18 Leyden jars of 0.013 microfarad capacity, to the helix, antennæ and to earth. The ground connection is here made to a system of water pipes. Such an equipment as the above is suitable for sending messages 300 miles over water and about 100 miles over land.

Some very interesting work in tuning or syntonic wireless telegraphy, showing the possibility of the De Forest system to operate simultaneously several different transmitters without interference is shown there every day. The receiving operator can, at will, attune his receivers to the messages from the Fort Wayne station, from the observation tower, or from the long-distance station on Art Hill. Although the station in the Electricity Building is only a quarter mile distant from this long-distance station, yet the operator there, with his receiver connected to a 75-foot antennæ wire, is utterly unaware of the transmission of messages from this large power station until he has attuned his instrument carefully to the wave



INTERIOR OF THE DE FOREST WIRELESS TELEGRAPH STATION IN THE OBSERVATION TOWER SHOWN ON THE OPPOSITE PAGE

length of that transmitter. Similarly, at the *Post-Dispatch* and *Star* stations downtown, the operators are receiving press dispatches continually from the observation tower while the Jerusalem station is transmitting to Springfield. On several occasions two operators, each with a distinct receiving and tuning apparatus, have been connected to the same receiving wire downtown, and one received dispatches from the long-distance station while the other operator has read messages from the observation tower.

Current Topics

A PECULIAR recent feature of machine tool design is the fitting of cranes as parts of the machines themselves, solely for hoisting pieces of work, or portions of the machines, which may have to be detached or changed frequently. Thus, many types of wheel lathes are provided with forms of hoists which are moved by the face-plates themselves, the latter revolving sufficiently to hoist a mounted pair of wheels into the centres. Axle-lathes also are provided with light cranes for lifting axles in and out,—an operation for which it is not worth taking up the time of the shop crane. Railway waggon and carriage wheel boring machines generally have a swinging jib crane, with suitable hooks for lifting the wheels on and off the table. One type of tool grinding machine is fitted with a little crane solely for the purpose of changing the emery wheels on the spindle, the wheels being too heavy for hand labour, and yet not heavy enough to make it desirable to call upon the shop crane. In such cases as these the addition of the crane makes the machine independent of outside aid in hoisting, and it may be located in any convenient position, regardless of the arrangement of shop cranes. Perhaps the most novel and recent development of this kind occurs in a pipe-turning and boring lathe, made by George Addy, of Sheffield, England, which is designed for operating on pipes up to 4 feet diameter and 15 feet long. The pipes are rolled down an inclined way onto the lathe, after which an hydraulic lift, of about 5-ton capacity, raises them into position for turning and boring. After this the lift again comes into play, and removes the pipe to another inclined plane leading direct into a railway truck, if desired. The employment of this device results in considerable time-saving.

THOSE who are in touch with foundry work are aware that it is being subject

to many changes. New buildings, new plant, new methods, the growth of foundry literature tread on one another's heels, and are apparent to all. One incident which is seldom noticed is the increasing complexity of some classes of castings, due to the practice of making parts in one that were formerly cast separately and bolted together, or which are required by new designs. This is especially noticeable in machine tools, where the box sections, the trays, and the numerous bosses increase the work of the patternmaker and the amount of coring out. These often affect and modify the direction of moulding, while at the same time the necessity of clean and sound metal becomes more difficult to satisfy. How best to make and mould the patterns of some present types of framings requires more than an off-hand settlement.

A NOISELESS typewriter is something devoutly to be wished for. The clatter of the average machine ought to have been a fruitful stimulus to inventors long ago, but typewriter ingenuities seem to have followed other lines rather than that of producing noiseless working, so that the problem is still an open one. Not only is the constant din of the machine nerve-straining to others than the operator, but from an engineering point of view it means wear and tear of mechanism and misspent energy,—imperfect design and construction,—which thoughtful consideration ought to overcome in measurable degree.

THE greatest cargo carrier in the world and the largest ship ever turned out from an American yard is the twin-screw steamship *Minnesota*, built for the Great Northern Steamship Company, for Pacific service, by the Eastern Shipbuilding Company, of New London, Conn. When fully laden with cargo and stores her displacement reaches the enormous figure of 33,000 tons. She is 630 feet long over all, has a beam of 73½ feet, and from the bottom of the keel to the top of the navigating bridge measures a little over 89 feet. At the ship's full draught of 33 feet, the navigating bridge will thus be 57 feet above the water-line. The triple-expansion engines are of 10,000 H. P., and steam

THE "MINNESOTA," THE LARGEST CARGO CARRIER IN THE WORLD AND THE LARGEST SHIP EVER BUILT IN THE UNITED STATES. LENGTH, 630 FEET; BEAM, 73½ FEET; DISPLACEMENT AT FULL LOAD DRAUGHT, 33,000 TONS

for them is supplied by Niclausse water-tube boilers. The ship is strengthened against hogging and sagging strains by a continuous central longitudinal bulkhead reaching from the keel to the upper deck, and affords the first instance of this form of construction. Electricity figures prominently in the equipment of the vessel. The lighting throughout is electric, the ventilating fans, steering gear, and cargo hoists are operated by electric power, and the staterooms, dining-rooms and library are warmed by electric heaters. The electric cargo hoists are thirty-two in number. One of the minor novelties in the ship is found in the abandonment of the conventional ratlines for getting aloft for steel-runged ladders attached directly to the hollow steel masts. Though designed primarily as a cargo ship, the *Minnesota* can carry 172 first-class passengers, 110 second-class, 68 third-class, and 2424 steerage passengers. Her speed is 14 knots.

A COMPARATIVELY new type of insulation for high-tension circuits and apparatus has lately been introduced in the United States by some of the electric cable manufacturers. It is known as varnished cambric insulation, and consists of strips of oiled linen cambric wound spirally over the conductor in as many layers as may be desired, practically as in the case of oil-saturated paper, varnish being applied between the several layers. The material in appearance and odour closely resembles oil silk and is very adhesive,—so much so that it is claimed for this insulation that it will exclude moisture indefinitely. The insulation has already been employed for high-tension, lead-covered cables in subways where there is danger of the lead becoming impaired through the action of acids or by electrolysis. It is also employed for insulating high-tension conductors behind switchboards and on transformers. Since this insulating material is not detrimentally affected by oil, as is rubber insulation, it may also be used to advantage in place of rubber insulation on the spark-coil circuits of gas engines, automobiles, etc. For the latter use the cambric insulation over the conductor is covered with a braid, to guard against abrasion. The insulation resistance and breaking-down test figures of this material are probably not higher than those of oil-saturated paper, and its general reliability and durability yet remain to be determined by actual extensive use in practice. Its cost is about equal to that of oil-saturated paper insulation.

ACCORDING to a recently circulated paragraph in German and French papers it had been contemplated on one of the Swiss railway lines to use electric power by placing electric heaters within the boilers of the locomotives and raise steam through their agency instead of that of coal, the electric current to be supplied by overhead trolley arrangement. The well-known electrical firm, Messrs. Brown, Boveri & Co., of Baden, Switzerland, however, have advised us that there is not any truth in the report and that, as might have been expected, such a plan for electric traction is entirely out of question, even in Switzerland with its abundance of readily available water power for electric service. "No one," they say, "ever, to our knowledge, seriously made a proposal of this kind."

THE operations of the Chinese steamship *Haimun*, which was chartered by the *London Times* and equipped with the DeForest wireless telegraph system for the purpose of gathering news in the war zone in the Far East, were watched with much interest, and it must be admitted that her career in this respect, while comparatively short, was highly successful. The reason given for the sudden cessation of operations was that the steamship required repairs and had proceeded to a Japanese port for that purpose. It developed later, however, that the movements of the vessel had been restricted by the Japanese

Government to points south of Pillar Rock on the Chinese coast, which restrictions had the practical effect of putting the *Haimun* out of commission. One reason for placing these restrictions on the movements of the vessel is said to be that the *Haimun's* wireless transmission interfered with the Japanese wireless operations up to a distance of one hundred miles. Another possible explanation may be that the news gathered, or that might be gathered, by the *Haimun*, as to the operations of the Japanese, and sent out to the four corners of the earth by cable, from Wei-hei-wei, where the wireless shore station was situated, did not accord with the well-established policy of the Japanese and, indeed, all naval and military authorities, to conceal their actions in every possible way from the enemy. If this policy prevails hereafter, as no doubt it will, the gathering of war news by wireless telegraphy or otherwise may be as difficult a matter at sea as it now appears to be on land.

ON one occasion when the *Haimun* was within twelve miles of Port Arthur the vessel was brought to by a shot from the Russian warship *Bayan*. She was presently boarded by two lieutenants, who proceeded to inspect her papers, the wireless telegraph apparatus, messages, etc. The correspondent of the London *Times*, Captain James, had, on the approach of the boarding crew, sent a wireless message to Wei-hei-wei, informing that station that they were about to be boarded by the Russians, and if nothing was heard from him within three hours to notify the commander of the British fleet at Wei-hei-wei and the London *Times* accordingly. During the inspection of the *Haimun* all the guns on one side of the *Bayan* were kept menacingly trained on the hull of the former, and those on that ship were for a time uncertain as to their fate. The boarding officers, however, were suddenly recalled by excited signals from the *Bayan*, which immediately returned to Port Arthur. It was surmised by the *Haimun's* officers as an explanation of the hurried return of the *Bayan* that the Russians had overheard wireless signals from Japanese warships. If this surmise be correct, and, indeed, whether correct or not in this particular instance, the possibility of such an occurrence would indicate that wireless silence may sometimes be golden if by speech the enemy is apprised of his adversary's presence or contemplated action. In this relation it may be noted that every telegraph operator acquires a style of transmitting the Morse alphabet that is peculiar to himself and by which his sending may be recognised by his fellow operators as readily as by his voice. Indeed, it is also a fact that so simple a piece of automatic telegraph apparatus as the well known messenger call-box transmits the signals representing the number of the box in so characteristic a manner that the central office clerk can determine from which box a call has emanated long before the number of the box is completed. Hence it is easy to understand that some characteristic of transmission or of the code employed in wireless telegraphy might readily convey to an operator familiar with those characteristics a knowledge of the presence of a friend or enemy, even though the signals themselves may be unintelligible.

WHILE the days of big chimneys for boiler plants may have been shortened somewhat by the development of artificial draught machinery, they are not yet of the past, nor has the business of steam distribution through city streets over long distances been crowded out of existence by the electric central station, despite the many attractive features of electric power service. An excellent illustration of this will be afforded by a chimney to be built for the New York Steam Company, whose steam service for heat and power through underground street mains has been in operation in the city of New York for the past twenty-three years. The chimney, which will form part of the up-town station of the company, is to be 300 feet high, circular in section, with an outside

diameter at its base of nearly 30 feet, tapering to about 17 feet at its apex. It will be built in twelve sections, with walls ranging in thickness from 32 inches at the lowest section to 11 inches at the topmost section. The weight of the chimney will be about 2200 tons, and its cost in the neighbourhood of $25,-000. It will be built of hollow moulded blocks.

"AUTOMOBILING" on the water is the decidedly expressive term applied to the use of the many high-speed motor boats which have latterly come into existence. While the hulls themselves of these boats are noteworthy combinations of lightness and strength, it is the internal combustion engines which drive them that command primary attention. Ten years ago there were comparatively few of them applied to pleasure boat service, and their installation was crude engineering in the light of what has since been accomplished. To-day they are found on the water everywhere. A score or more of builders are turning them out, and while the boats are not all of the "automobile" variety, with speed as the principal characteristic, they have all but driven the small pleasure steam launch out of use.

MARCO POLO, the Portuguese, was the first European since the days of Greek and Roman ascendency to explore the remote parts of Asia. This was in the latter part of the thirteenth century. A correspondent of the *Bulletin* of the Iron & Steel Association, in looking through Marco Polo's account of his travels, found the following reference to "stones which are burnt instead of wood":—"It may be observed, also, that throughout the whole province of Cathay there are a kind of black stones cut from the mountains in veins, which burn like logs. They maintain the fire better than wood. If you put them on in the evening they will preserve it the whole night, and will be found burning in the morning. Throughout the whole of Cathay this fuel is used. They have also wood indeed, but the stones are much less expensive." This early reference to coal is of especial value because it shows that the Chinese possessed a knowledge of its use six hundred years ago, before coal was much used in Europe.

THE latest addition to the United States Navy is the 16,000-ton, twin-screw, first-class battleship *Louisiana*, launched a little over a month ago at the yards of the Newport News Shipbuilding & Dry Dock Company, at Newport News, Va. The ship is 450 feet long and of 75 feet 8 inches beam, with a draught of 24 feet 6 inches. She is to have a speed of 18 knots, and a complement of 41 officers and 778 men. Her triple-expansion engines, to develop 16,500 H. P. in two sets, will have 32½-inch high-pressure and 53-inch intermediate cylinders, and two 61-inch low-pressure cylinders, with a 48-inch stroke. Steam will be furnished by twelve Babcock & Wilcox water-tube boilers. The water-line armour belt will be 11 inches thick at the top at the machinery compartments, tapering to 9 inches at the bottom. Forward and aft the armour will step down to 9 inches at the top and 7 inches at the bottom, then to 7 inches at the top and 5 inches at the bottom, then to 5 inches constant thickness, and then to 4 inches constant thickness. There will be lower casemate armour 6 inches thick and upper casemate armour 7 inches thick. The 12-inch turret armour will be 12 inches thick on the port plates, and 8 inches on the sides and back; the 8-inch turret armour will be 6½ inches thick on the port plates and 6 inches thick on the sides and back. The main battery will consist of four 12-inch breechloading rifles, mounted in two turrets, one forward and one aft, and eight 8-inch breechloading rifles, mounted in four side turrets. There will be a secondary battery of twenty 3-inch (14-pounder) rapid-fire guns, twelve 3-pounder semi-automatic guns, six 1-pounder auto-

matic guns, two 1-pounder semi-automatic guns, two 3-inch field pieces, two machine guns of 0.30 calibre, and six automatic guns of 0.30 calibre. There will also be four 21-inch submerged torpedo tubes.

THE *Stateman's Year Book* for 1904 contains an interesting chart showing the number of ships in the principal navies of the world which were fitted wholly or partially with water-tube boilers at the beginning of the present year. According to this, Belleville boilers are in the lead, with 171 ships to their credit. Then comes the Thornycroft boiler with 51 ships; the Niclausse boiler, with 50; the Babcock & Wilcox, with 40; and the Yarrow boiler with 39. The Normand or Normand-Sigurdy boiler is in use on only 16 vessels, and the D'Allest and the Dürr boilers are each represented on 14. In the British, French, Russian and Japanese navies the Belleville boiler predominates among the water-tube kind; in the German navy the Thornycroft is at the head of the list; and in the United States navy the Babcock & Wilcox boiler is the favourite.

MEXICO, outside of its interest to the tourist and historian, has been a prominent field to which the attention of the investor has been directed for a number of years. The rapid building of railroads, so efficiently promoted by President Diaz, has doubtless contributed largely to the rapid advance made by Mexico during recent years. The man seeking investment has also been attracted to this country, conspicuous during these times by absence of organised labour disturbances. Most opportunely for those interested, comes a consular report treating of the opportunities for employment in Mexico. Vice-Consul-General Edward M. Couley states that, in general, Mexico is no place for a man without capital. It is a new country, in the sense that it possesses great natural resources as yet undeveloped; but most of these can be developed only by the aid of capital. Modern machinery and modern transportation facilities will enable the man with abundant capital to profitably exploit the natural resources of the country; but he must also have men with brains, technical education, and adaptability. There is room for the engineer,—electrical, mining, mechanical, or civil,—the architect, the veterinarian, the scientific agriculturist, the practical man in any line. If he has such an education, good health, and possesses the stuff that pioneers are made of, the chances are that he will be ultimately successful in Mexico, from a pecuniary standpoint. A prime requisite for any person who desires to go to that country, however, to earn his living, is a knowledge of Spanish. Without a good working knowledge of this his chances for doing well are much handicapped.

UNDER the wise guidance of President Diaz, a middle class is developing in Mexico, and technical schools are being established. Mexicans are just beginning to realise that there is a great field for young men with a technical education, and the boys of the upper classes, as well as the growing middle class, are beginning to fit themselves to take an active part in the development of the resources of their own country. Mr. Couley adds that Mexico does not need budding doctors, dentists, druggists, opticians or lawyers; she already has a surplus in these professions. Undoubtedly one of the reasons for the lack of greater industrial progress in Mexico heretofore has been the fact that, broadly speaking, there have been only two classes,—the very rich and the very poor. The boys of the upper classes have all been educated to be professional men, and the boys of the lower classes have practically had no education. A fact having an important bearing upon the situation to anyone considering locating in Mexico is that, generally speaking, salaries there are lower than for corresponding positions in the neighbouring United States, for example, and the cost of living is just as

great or greater. A salary of $225 a month, Mexican currency, sounds bigger than a salary of $100 a month, United States currency; but in point of fact its purchasing power is not any greater.

THE average young American or Englishman does not realise the advantages of living in his own country, nor the sacrifices that must be made in going to a foreign one, especially such a country as Mexico. If he is working at home, he is obliged to compete with other young men who are just as bright, or brighter, than he is, and he, therefore, has every incentive to do the best work of which he is capable. He has the example of older, successful men before him, and takes his orders from men who understand their business thoroughly, and from whom he is always learning something. He lives in an air of progress, and if there is anything in him he is going to progress. Going to Mexico is different. One leaves behind his accustomed manner of living, the social and educational advantages to be found in the home country, and the stimulus of competition and emulation. He not only has to earn his living, but he has to make a new place for himself in what is, to all intents and purposes, a new world; he has to create for himself a new environment. All that he was able to get out of his environment before, he now has to get out of himself, and he is just as likely to go backward as forward, if not more so. When in an atmosphere where everybody is working at high pressure he is obliged to follow suit. He may bestir himself for awhile after he gets to Mexico; he usually does, and brings on illness by his over-energy at the start. But by the time his blood thins out, when he has learned the language, manners and customs of the country, and is, therefore, ready to accomplish something, he begins to realise that the people who have lived there for four hundred years really do know something about living there. He begins to appreciate that he cannot do so much work in the thin air of the high tablelands or the tropical heat of the lower regions of Mexico. Everybody is easy-going, and he will become so in time. It has been a matter of speculation as to what would have been the present condition of Mexico if the Pilgrim Fathers had landed at Vera Cruz instead of at Plymouth Rock. Perhaps it would not be so very much different from what it is. It has been shown in actual experience, says Mr. Couley, that Americans and Englishmen who have emigrated to Mexico have, after the second generation, lost most of their original characteristics, including their energy. Nevertheless, if a young man wishes to go to a foreign country to hew out his destiny, there is probably no better country to go to than Mexico. Its government is stable, it is prosperous, all lines of business and industry are active, and it possesses great possibilities. Any person who goes there, however, should be fully equipped to do at least one thing well. There is no room there for the young man who is "willing to do anything," but is not fitted for any particular thing.

IRON ore production in the United States in 1903, as reported for the United States Geological Survey by John Birkinbine, amounted to 35,019,308 long tons. This, while about half a million tons less than the output in 1902, is still the second largest quantity on record, and is greater than the combined totals of Germany and Luxemburg and of the British Empire (the nearest competitors of the United States) in the year 1902. The data for 1903 for the countries named are not yet available, but the same comparison will probably prove true for that year also. The average iron content of the ore mined in the United States is also higher than that obtained in the two countries mentioned, and, therefore, the ore can yield a greater amount of pig iron. Iron ore statistics were first collected by the United States Geological Survey in 1889, when the output was only 14,518,041 tons. The yearly average for the twenty years is somewhat over 20,-

000,000 tons. This average also exceeded the maximum output of any other country in any one year until last year, when the combined yields of Germany and Luxemburg were 21,230,639 metric tons. The iron ore obtained in the United States in 1903 came from twenty-two States and two Territories, Vermont and Montana reporting no ore mined in that year. Minnesota heads the list with 15,371,396 tons; next comes Michigan with 10,600,330 tons; then Alabama with 3,684,960; and after that there is a drop below the million-ton mark, with Tennessee highest, at 852,704 tons, and Maryland lowest, with only 9920 tons.

THE Lake Superior district stands pre-eminent as a producer of iron ore, its annual output exceeding that of any foreign country and the average character of the ore being excellent. In the year 1903 there was obtained from the Mesabi and Vermilion ranges in Minnesota, the Marquette Range in Michigan, and the Menominee and Gogebic ranges in Michigan and Wisconsin, a total of 26,573,271 long tons of iron ore. Of this ore 51 per cent., or 13,452,812 long tons, were obtained from the Mesabi Range; 15 per cent., or 4,093,320 tons, were won from the Menominee; 14 per cent., or 3,686,214 tons, were mined on the Marquette Range; 13 per cent., or 3,422,341 tons, came from the Gogebic Range; and 7 per cent., or 1,918,584 tons, were credited to the Vermilion Range. In addition to the above-named ranges in the United States, which by common consent compose the Lake Superior iron ore region, a sixth, the Michipicoten Range, was opened in Canada in the year 1900; but its product in 1903, 223,976 long tons, is not included in the above data. The total production of the Michipicoten Range to the close of the year 1903 is only 815,152 long tons. The greater portion of this ore has been sent to the United States, and is non-Bessemer in character.

CHARLES L. EDGAR

President of the Boston Edison Company

A BIOGRAPHICAL SKETCH

By La Rue Vredenburgh

THE development of all new enterprises during their periods of infancy and adolescence, and until their products have become matters of world-wide use and universal recognition, is invariably associated with the names of those men who, by their efforts, have contributed actively to this development. Directly and intimately associated with the science of central station generation and distribution of electricity is the name of Charles L. Edgar, of Boston, which stands for all that is enterprising and progressive along this line, and is familiar to all who have watched the wonderful advancement and growth of this science.

Mr. Edgar was born on December 23, 1860, in the village of Griggstown, N. J., located on the Delaware & Raritan Canal in Somerset County. His father, Thomas Edgar, was a substantial and well-known citizen, and was engaged for a number of years in the milling business at this point. After acquiring such education as was possible in the district school located near the place of his birth, he entered the preparatory school for Rutgers College, at New Brunswick, N. J., in 1875, and in due time entered the college, taking the regular academic or classical course, graduating in 1882, taking second honour, and delivering the English saluta-

tory address on the Commencement stage. After graduating, recognising the growing importance of applied electricity, he took a six months' post graduate course in electrical engineering under Professor Francis Cuyler Van Dyck, of the above institution. In January, 1883, he reported to Mr. Edison at his laboratory at Menlo Park, and was immediately sent to the testing department of the Edison Machine Works, in Goerck Street, in the city of New York, and remained there for nine months, reporting to Mr. C. L. Clark, chief engineer of the Edison Lighting Company. From here he was transferred to the works of the Bergman Company, manufacturers of central station apparatus. After one month spent here he was transferred to the Edison Company for Isolated Lighting, and from that time until 1887 was employed by this company in general engineering work and installing small central stations throughout New York and Pennsylvania.

In August of that year he was sent by the parent company to Boston and given the position of general superintendent of the Edison Electric Illuminating Company of that city. Two years later he was made general manager, and was elected to the vice-presidency early in the 90's. He filled the position of vice-president and general manager until 1900, when, on the death of Mr. Jacob Rogers, he was elected president of the company, which position he holds at the present time.

Mr. Edgar was president of the Association of Edison Illuminating Companies for the years 1893 to 1895, was vice-president of the National Electric Light Association in 1893, 1902 and 1903, and was president in 1904. He has also held the position of president of the Massachusetts Electric Light Association for the last three years, is at the present time chairman of the Boston branch of the American Institute of Electrical Engineers, and was also chairman of the local entertainment committee of the International Electrical Congress last month.

The phenomenal growth and advancement of the Edison Company, of Boston, can be attributed almost wholly to the activity and enterprise of Mr. Edgar, and the fact that this company to-day stands as an exponent of all that is up to date in central station generation and distribution is due to his untiring efforts to establish there the most improved and perfected methods. The introduction of the vertical engine and the storage battery in central station equipment are the features with which his name has been most markedly associated. The vertical engine was adopted in the station of the Edison Company, of Boston, as the result of a thorough investigation by Mr. Edgar in 1890, when he made a European trip for the special purpose of investigating this subject, visiting the largest central stations in Great Britain and on the Continent of Europe and thoroughly familiarising himself with the advantages of this type of engine as used abroad. In 1893 he took another trip through Europe for the purpose of investigating the subject of storage battery installation in central stations, and as a result the first equipment of this sort in America was made in the station of the Edison Company, of Boston. Again in 1898 Mr. Edgar visited England for the purpose of looking into what is known as the "Wright Demand" system, as used by the lighting company of Brighton, England, and upon his return the "Wright Demand Meter" was adopted by the Boston company, and is still in use there. Mr. Edgar has made several other trips abroad for the purpose of investigating foreign methods, with a view to giving his company the benefit of such features as, in his judgment, could be advantageously applied at home, especially in the line of central station construction.

Mr. Edgar is a man of most pleasing personality, and one whose influence is immediately felt by all with whom he comes in contact, both socially or in a business way, and, in spite of his success, he has always retained the most democratic attributes. One of his most remarkable qualifications is his ability to observe and control the most minute details connected with the vast business of which he is the head.

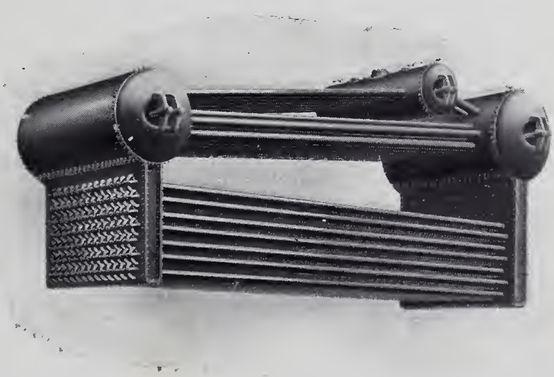
Manufacturing News

A NEW water-tube boiler has been placed on the market by the Atlas Engine Works, of Indianapolis, Ind., in which the builders believe they have eliminated practically all the difficulties heretofore experienced with this type of boiler. It is claimed that this boiler purifies its own feed-water, superheats the steam and provides for a practically unimpeded circulation. It is a horizontal boiler, composed of two water legs, three drums running across the setting and connecting tubes, as shown in the illustration.

A New Water-Tube Boiler

The rear and front drums are made of continuations of the same plates that form the rear and front water legs, a method of construction that prevents a seam of any kind from being exposed to the flames or hot gases. The legs open into these drums the full length of the drums, thus avoiding the contraction at the throat which impedes circulation in so many of the water-tube boilers. In the rear drum is located a live steam purifier, independent of the drum, and so arranged that it can be blown out at any time without interfering with the operation of the boiler.

The generating tubes between the water legs are set on a slight incline, and each is accessible by a separate handhole in the water leg at each end. Equalising tubes between the front and rear drums help to perfect the circulation and keep an equal water level in both these drums. Superheating tubes entering these drums above the water line carry the steam to the middle or



A NEW WATER-TUBE BOILER MADE BY THE ATLAS ENGINE WORKS INDIANAPOLIS IND.

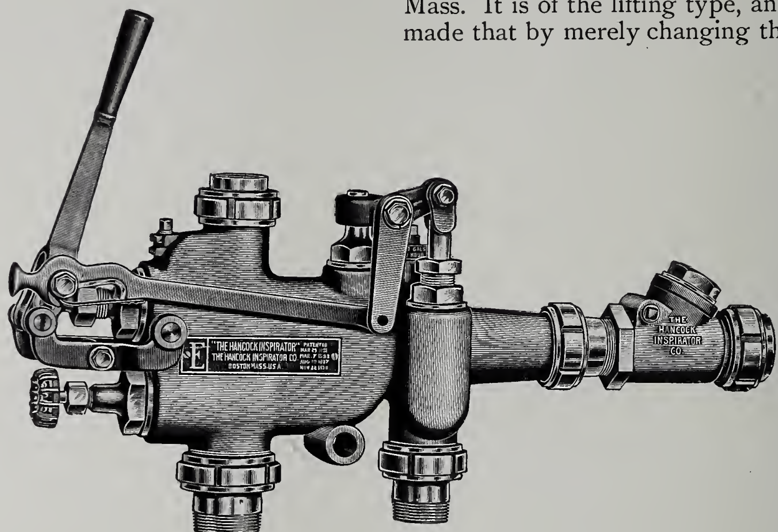
steam drum, whence it is piped for use. The boiler is built in sizes ranging from 100 horse-power upward, and can be erected and shipped as a whole, or in sections, in which latter case all the riveting is done at the shops and the tubes are expanded into the legs and drums after delivery.

The builders claim for this boiler that not only dry, but superheated steam as well is assured, making it impossible to throw water into a cylinder or give wet steam. The purification of the water also will give long life to the boiler and require less fuel and labour. The facilities for cleaning are ample, manholes giving access to the drums, and all the tubes carrying water being straight and readily accessible. The superheating tubes, carrying steam only, are slightly curved to take care of the expansion. By getting all seams away from the fire and hot gases, the builders believe they have eliminated the possibility of leaks at the rivets, or plates cracking from the rivet holes to the edge. The masonry required is simple and comparatively inexpensive, consisting of straight side walls and bridge walls, with no overhanging walls between or to the drums, The materials used and the workmanship throughout are of the best.

The Hancock Locomotive Inspirator

A LOCOMOTIVE inspirator, designed to meet the present demand of railroads in standardising their equipment, is the latest production of the Hancock Inspirator Company, Boston, Mass. It is of the lifting type, and is so made that by merely changing the nozzles and tubes it will be capable of delivering maximum capacities ranging from 2500 to 5000 gallons per hour at a steam pressure of 200 lbs. per square inch, lifting water 4 feet vertically with the feed-water at 75 degrees F. By its use railroads are able to have one standard size inspirator for all sizes of locomotives, it being only necessary to insert in the inspirator the nozzles and tubes for the proper capacity to supply the locomotive. Thus only one size of spare inspirators and but one size of repair parts are required.

In principle, this inspirator is similar to the other Hancock inspirators. It comprises a lifting apparatus, which lifts the water, and a forcing apparatus, which forces the water into the boiler,



A NEW LOCOMOTIVE INSPIRATOR MADE BY THE HANCOCK INSPIRATOR CO., BOSTON, MASS.

the lifting apparatus acting as a governor, delivering the proper amount of water to the forcing apparatus for the proper condensation of the steam.

The inspirator is capable of feeding the boiler at any steam pressure between 35 lbs. and 350 lbs. per square inch without any adjustment of either the steam or water supply, and when the inspirator is in full working position at any steam pressure between these limits it cannot discharge the water except through the delivery pipe leading into the boiler. It will handle hot feed-water, and, from tests, it has been found that it will start and feed the boiler reliably with the supply water at 135 degrees F. with 110 lbs. steam pressure, at 137 degrees with 140 lbs. pressure, at 135 degrees with 160 lbs. pressure, at 130 degrees with 200 lbs. pressure, and at 123 degrees with 225 lbs. pressure.

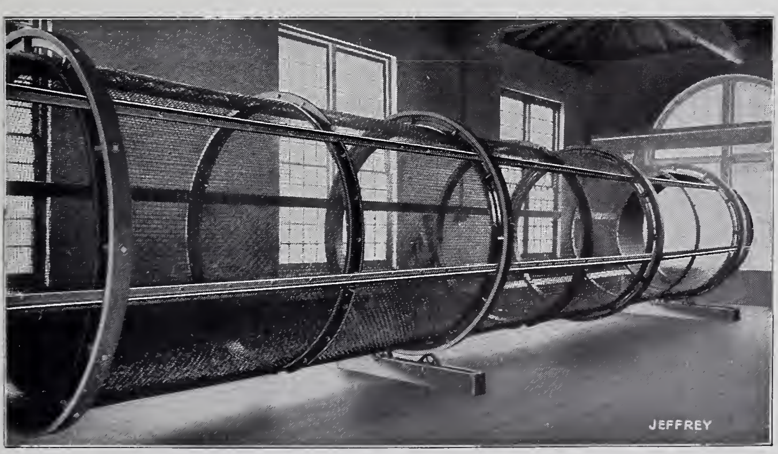
The capacity of each set of nozzles and tubes can be regulated for light or heavy service of the locomotive. It has been found that with cold feed-water the minimum capacities will not be more than 45 per cent. of the maximum capacity with 160 lbs. steam pressure, 48 per cent. with 200 lbs. pressure, and 54 per cent. with 225 lbs. pressure. A minimum capacity as low as 1100 gallons per hour may be obtained when the 2500-gallon nozzles and tubes are used in the inspirator.

A Large Coal Screen

THE accompanying side-view illustration shows an extraordinarily large revolving screen built by the Jeffrey Manufacturing Company, of Columbus, Ohio. It is 7 feet in diameter and 54 feet long, mounted on friction rollers. This screen is for separating coal into a number of sizes, and was built especially for one of the large coal companies in Virginia.

As will be seen from the illustration, the screen has no central shaft, but is supported on friction rollers. When installed at the mine, the screen will be supported on heavy friction rollers carried on shafts extending the full length of the screen. These rollers bear against the friction rings attached to the outside of the screen, rotation of the shafts thereby causing rotation of the screen.

The coal is fed into the screen by means of a special bucket elevator at the rate of about 250 to 275 tons per hour. This type of screen is also suitable for screening shavings in large quantities, and is a fair example of what the Jeffrey Manufacturing Company is able to turn out in this line of work.



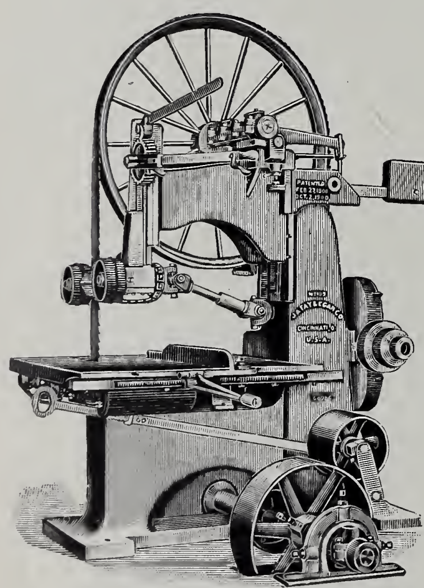
A LARGE COAL SCREEN BUILT BY THE JEFFREY MANUFACTURING CO., COLUMBUS, OHIO

A NEW automatic band rip-saw has recently been placed upon the market by J. A. Fay & Egan Company, of Cincinnati. The makers recommend it to car builders and other woodworkers handling heavy stock, as the machine is built for heavy work. The machine is safe to operate, and requires but a small amount of power.

A New Band Rip-Saw

The table, always at a standard height, is provided with rolls closely spaced to allow short pieces to be fed to the saw. The adjustment of fences and rolls is easily effected, and the powerfully-driven feed rolls in the table and above it are thrown in and out of gear or stopped altogether by the movement of a single lever within easy reach of the operator. The work may be fed to the machine by either hand or power, as desired, by the operation of this lever.

The straining device which controls the upper wheel and the path of the saw blade on the face of the wheels is very sensitive, and readily takes up the slack in the saw blade, imparting a smooth motion, and, it is said, a longer life to it. As may be seen in the cut which is shown herewith, the lower wheel is solid, lessening the circulation of dust and air, and giving itself increased momentum, so that its speed governs the upper wheel and prevents it from overrunning the lower.



AUTOMATIC BAND RIP SAW MANUFACTURED BY THE J. A. FAY & EGAN COMPANY, CINCINNATI, O.

The saw removes only a small kerf, and seems to be admirably adapted to reducing large timbers to smaller dimensions, ripping wide lumber into strips of varying widths, resawing from the side of timber, and other similar work.

THE accompanying illustration shows a metal-melting furnace, manufactured by the Lunkenheimer Company, Cincinnati, Ohio, which has been found to afford a very efficient and economical method of melting metals, particularly brasses and bronzes.

A Metal-Melting Furnace

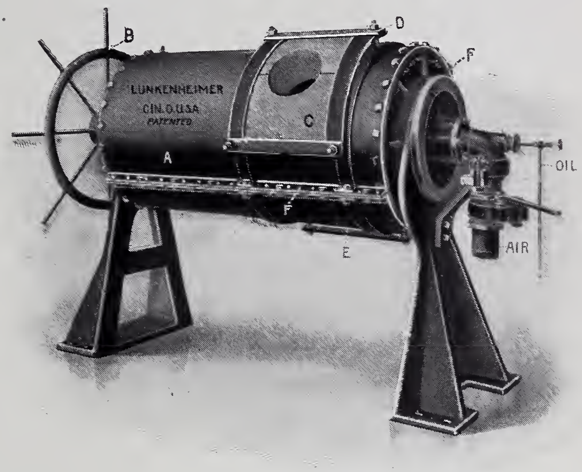
This type of furnace was evolved after considerable experimenting with nearly every type of furnace on the market, and is the result of considerable study on this subject. As will be seen from the cut, the furnace consists of a cylindrical sheet-steel drum *A*, having cast iron heads. The interior of the drum is lined with fireproof tile, and there are two openings on opposite sides of the drum. Only one of these openings is in use, the other being closed by a fire-clay filling. The object of having two openings is to increase the life of the linings of the furnace. It has been found that the furnace wears out quicker around the filling hole (which also serves as outlet for the flame) than elsewhere. One of the advantages of this type of furnace is that when one filling hole is worn out it can be closed by a fire-clay filling and plate, the furnace reversed, and the other hole cut out and put in service.

The oil burner is of a special type, designed to give the greatest amount of heat with a minimum consumption of oil. In the Lunkenheimer foundry there are ten of these furnaces in use, and it is possible to secure from six to

seven heats per working day of ten hours from each furnace. The weight of each heat will average about 550 pounds, and the oil consumption varies from two to two and one-half gallons of crude oil per hundred pounds of metal melted.

The life of the linings is from three to four hundred heats, varying with the kind of metal melted. The whole furnace is of a heavy and substantial construction, and will be found very durable. On account of the simple form of the tile it is very easy to reline.

This furnace is made in two sizes, the No. 1 size having a capacity of 550 pounds of metal per heat, and the No. 2 size having a capacity of 1200 pounds of metal per heat.



A METAL MELTING FURNACE MADE BY THE LUNKENHEIMER CO., CINCINNATI, OHIO

American Well-Boring Machinery for China

ACCORDING to a recent report by United States Consul William Martin, at Nankin, that city, though the southern capital of China, does not possess a waterworks system. Foreigners of various nationalities are trying to secure the franchise, but the conditions specified seem to be such that the authorities do not care to comply with them.

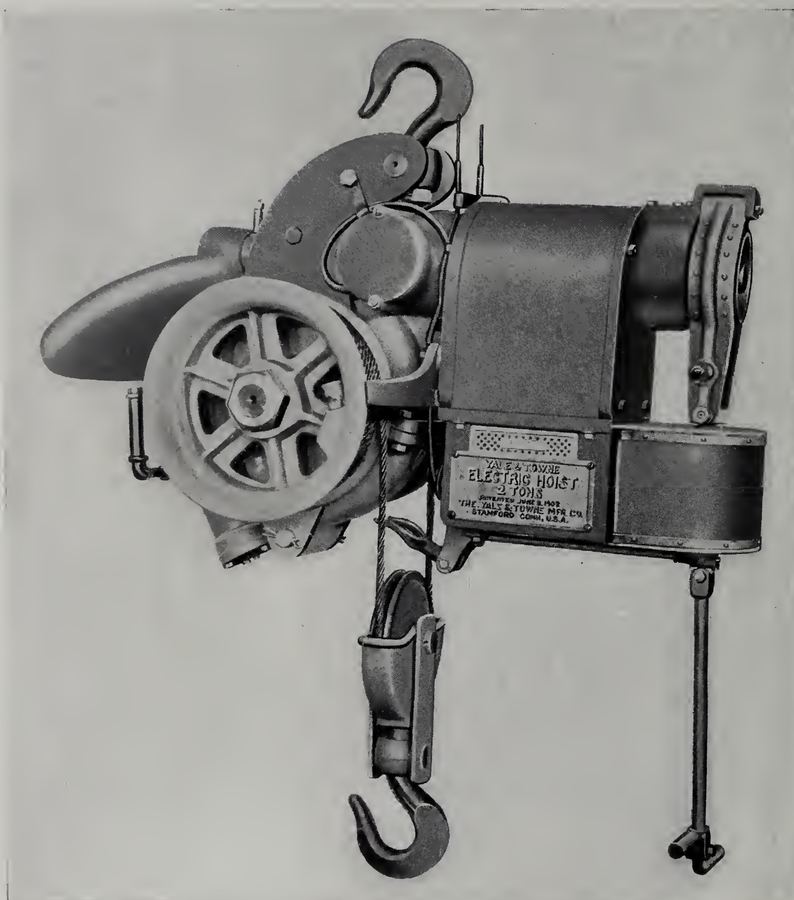
The season has been an unusually dry one and the question of a water supply has been agitated. Many foreigners have been compelled to hire carriers to bring water from the Yangtze for drinking purposes, but they can never be sure it is not taken from some filthy creek. When about to move into the new consulate building, Mr. Martin resolved, if possible, to secure a well free from surface drainage and containing pure water. With that end in view, he had made (from drawings) a "drive point," and proceeded to "drive" a well as it is often done in certain localities in the United States. At 30 feet (about 4 feet below low-water mark in the Yangtze) he found a strata of sand with an apparently inexhaustible supply of clear, pure water. The "American well," as it is called, soon attracted the attention of high officials living in the city, who, one after another, came to see and test it. The result of their investigations was the setting apart of an amount of money to be used in securing like wells about the city, to the number of one hundred. The fantai, a man next in rank to the viceroy, came at the viceroy's request and asked Mr. Martin to aid them in the work. Tests showed that the soil was adapted for the wells only here and there, and Mr. Martin therefore advised against the expenditure and suggested artesian wells, with storage for fire purposes, as preferable.

The advice has not yet been acted upon, but the reputation of the American well has spread until from different parts of the province, as well as from Ningpo and Tsingkiang, come requests for aid in securing a good supply of water by pumps.

Mr. Martin believes there is a good opening in China for a few persons who understand sinking artesian wells and other methods of securing a good supply of pure water. Waterworks are un-

known in China outside of foreign concessions.

There came to the consul's office recently, accompanied by the taotai of foreign affairs in this city, a Mr. Chang Ching (known as the "Optimus" of China—that is, the man who has passed the highest rank in the highest examinations), who said he was much interested in deep-well work, and that he had organised a company, which had purchased over 1000 acres of land with the intention of utilising it for cotton raising and other agriculture. He wished to know about American machines for diking, deep-well boring, and windmills. If manufacturers of these machines will send to Mr. Martin catalogues with prices and probable freight cost of their various products from New York to Shanghai, he will see that they are put where they will do the most good. The prices required are the net ones to the purchaser.

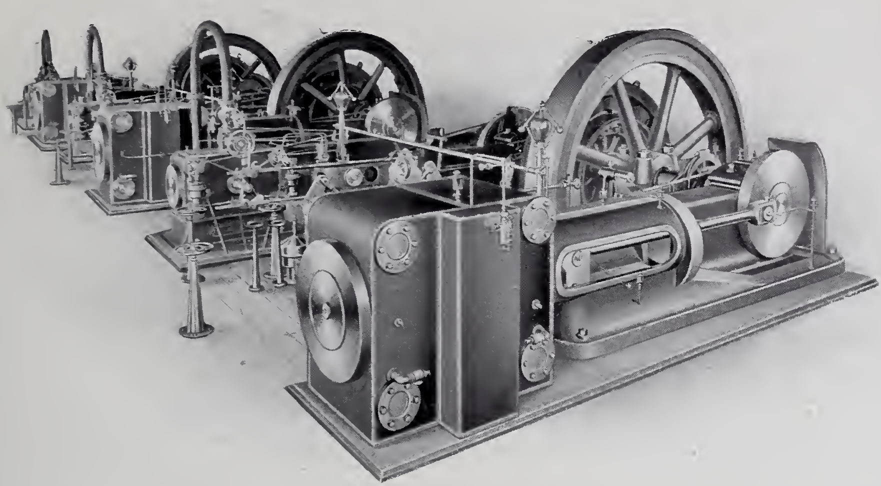


A NEW ELECTRIC HOIST MADE BY THE YALE & TOWNE MANUFACTURING CO., STAMFORD, CONN.

A Portable Electric Hoist

A NEW electric hoist, built by the Yale & Towne Manufacturing Company, of Stamford, Conn., is shown on this page. It is designed to permit its being moved from one place to another as easily as a chain block.

The motor is enclosed in a dust-



CROSS-COMPOUND DIRECT-CONNECTED CORLISS ENGINES MADE BY THE MURRAY IRON WORKS COMPANY, BURLINGTON, IOWA

proof case above the oil-submerged parts of the hoist, the motor shaft bearings preventing the possibility of oil entering the motor. The motor shaft is connected by bevel gears with the worm shaft, the worm engaging with the gear on the drum. All the working parts are enclosed in an oil-tight iron casing which excludes dust and water and at the same time insures thorough lubrication.

The load is taken on steel wire hoisting rope wound on grooved drums, which, with the worm wheel, are fastened to the main shaft. The hoist is arranged to balance on the upper hook whether loaded or empty, and to pull in a vertical line throughout the lift. An automatic cut-off is provided to prevent the load being hoisted too high, and to prevent the load running away even though the motor or brake should become inoperative. The hoist is provided with an extension rod to allow operation from the floor, where the operator may have a full view of the work.

It may be used in any part of the works or yards where current is available, and its use in connection with a hand crane greatly increases the efficiency of the latter. It is made to withstand rough usage in inexperienced hands. These hoists are made in five standard sizes.

Cross-compound, Direct-connected Corliss Engines

ONE of the many engine installations of the Murray Iron Works Company, of Burlington, Ia., is that at the works of the Hudson Portland Cement Company, Hudson, N. Y. As will be seen from the annexed illustration, the engines are of the cross-compound type, and are direct connected to generators of 450 KW capacity; they are run condensing, and together develop 2500 horse-power with 150 pounds steam pressure.

The high-pressure cylinders are 20 inches in diameter, and the low-pressure cylinders 40 inches, the stroke being 48 inches. The fly-wheels are 16 feet in diameter and weigh 60,000 pounds each. The crank-pins are 6½ inches in diameter and 7 inches long, and the cross-head pins are of the same length, with a diameter of 5½ inches. The shafts are 18 inches in diameter.

In the valve gear, the knock-off lever is fitted with double cams for use with an automatic safety stop motion, which shuts down the engine should the governor belt break or the governor be stopped by accident. The catch plates are made of hardened steel, and have eight wearing edges each.

The pistons are pressed on the rods by hydraulic pressure, each being, moreover, secured by a nut. The cross-

heads are fitted with babbitted shoes, and wedge adjustments are provided for taking up wear. The piston rod is threaded in the cross-head and secured by a jamb-nut.

The connecting-rods are provided at both ends with brasses adjusted by wide-faced wedge blocks. An adjustable pillow block is also provided for maintaining the proper alignment of shafting.

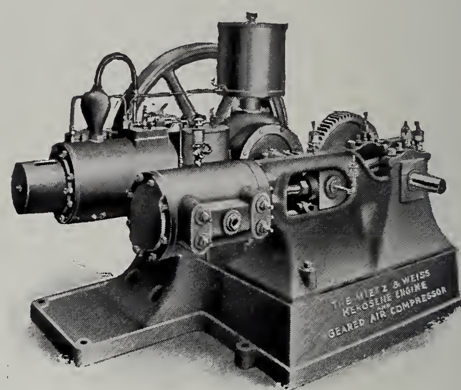
The governors are of the centre-weight, high-speed type, the centre weight having a cavity in the top to receive shot or a spring for adjusting the speed. Auxiliary governors are also connected to safety stop valves.

The current generated by these units is distributed to motors in different portions of the works.

The Mietz & Weiss Kerosene Oil Engine

THE well-established position of the gas or oil engine as an auxiliary in building construction, or for furnishing power where but a temporary plant is required, is exemplified in the erection of a new building at Forty-second street and Park avenue, New York. In the basement of this building the contractors have installed a kerosene oil engine, made by August Mietz, of New York, geared to an air compressor, made by the Clayton Air Compressor Works, of Brooklyn. The illustration on this page shows the engine and compressor as installed in the building.

The compressor is of the double-acting type, with a cylinder 8 by 8 inches, and compresses 70 cubic feet of free air per minute, at a pressure of 80 pounds. The compressed air is stored in a tank 6 feet by 18 inches, and furnishes power for operating five air drills used in connection with the structural iron work. The engine runs at a speed of approximately 450 revolutions per minute, and drives the compressors through gearing of a ratio of 1 to 5. The horse-power developed is approximately 10. The engine consumes 9 gallons of kerosene during the daily run of 10 hours.

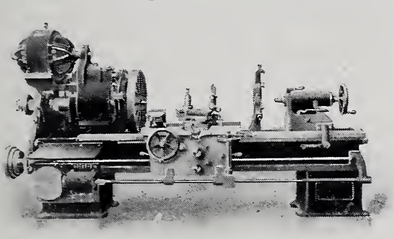


A MIETZ & WEISS ENGINE, MADE BY AUGUST MIETZ, NEW YORK, GEARED TO AN AIR COMPRESSOR MADE BY THE CLAYTON AIRC OMPRESSOR WORKS, BROOKLYN

One interesting feature of the engine is the method employed to prevent carburization of the cylinder walls. The cooling water, after circulating around the engine cylinder jacket, passes to a trap fixed on the side of the cylinder, from which the steam developed by the heat of the cylinder walls is conducted to be mixed with the air for the explosive mixture. A ball float in the trap keeps the water at a constant level. It is claimed that by this method of introducing moisture into the explosive mixture carburization of the cylinder walls is prevented.

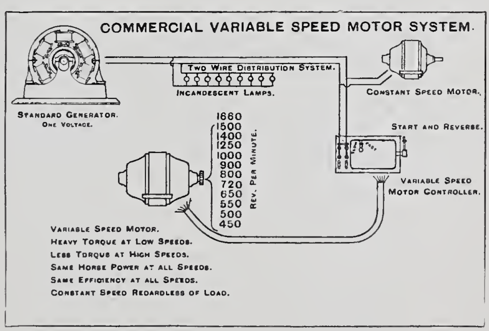
A SIMPLE SYSTEM OF VARIABLE SPEED ELECTRICAL DRIVE FOR MACHINE TOOLS

A SYSTEM of variable speed electric drive for machine tools which will be free from the complication of multiple systems of wiring and special generating devices, as well as from the inefficiency and unsatisfactory regulation of rheostatic methods of control, has long been sought by electrical engineers in charge of the equipment of modern machine shops.



The necessity which has heretofore existed for the installation of special generating plants and wiring systems wherever an efficient method of speed variation has been required, has been absolutely prohibitive to the introduction of variable speed motors in small numbers or in single units in many plants where their use would effect a great saving and where a gradual change to the individual drive system could be made were not the expense of such a radical change in equipment prohibitive at any one time.

The system illustrated herewith provides for the installation of a single unit or any number of electrically-driven tools on an existing generating and wiring system of absolute standard construction, and fulfills perfectly all the requirements for the operation of variable speed machine tools, such as lathes, boring mills, etc., which require an increase of the torque or pulling power at the slowest speed, and decrease of the torque at high speeds, with a practically constant horse-power output at all speeds and with constant speed at any desired point, whether the tool is cutting or not, and without waste of power in controlling resistances.



The motor which accomplishes this result is a double commutator machine having two windings with a different number of turns, but each winding of the same size wire and of the same ampere capacity. This is combined with a speed controller for making various combinations of these armature windings and for varying the field strength of the motor to secure a gradual change of speed between the different armature combinations. The controller also has a rotary starting and reversing switch, by means of which the motor is started, stopped and reversed, while the speed-controlling handle is set at any desired point. The controller is simple and compact, and may be placed at any desired position on the machine tool and operated by handles in convenient reach of the workman.

Standard equipments give twelve (12) speeds in either direction, with a range of speed of four to one from highest to lowest. The illustrations show the simple method of application of one of these motors to an existing two-wire system on which lamps and constant speed motors may also be used and the application of the motor and controller to a well-known make of engine lathe.

This system is known as the Commercial Variable Speed Motor System, and is manufactured by the Commercial Electric Company, of Indianapolis, Ind.

WHY STORAGE BATTERIES ARE SOMETIMES UNJUSTLY CONDEMNED

TO the average user the storage battery or electric accumulator is a thing of mystery—that box of cells which receives the unseen impulses of the electric current, later to give forth this latent energy to produce light, or power to propel the electric vehicle. One finds in this battery, also, a willing and very useful servant when well treated, but one quick to resent abuse resulting from carelessness or ignorance.

Few owners have either the time or inclination to familiarize themselves with the theory of the complex details of the chemical and electric processes by which the materials of the plates and solution of the secondary battery are so changed, in the process of charging, as to accumulate energy, which can later be given off in quantities sufficient for practical use. There are, however, simple, practical details, careful attention to which will more than repay the owner of a battery in lengthened life of plates, greater efficiency and freedom from petty annoyance.

The keystone of the arch of carefulness is *purity*.

For purity of material in the plates, and their correct composition and adaptability to the purposes desired, one must, of course, look to the manufacturers, and hold them responsible for faults in construction.

The conditions attendant upon the maintenance of the battery are, however, directly under the owner's control, and it is here that the balance of troubles arise. Storage battery troubles can nearly always be traced to carelessness in manipulation or to impure chemicals.

The "electrolyte," or solution surrounding the lead plates of a secondary battery, is often an offender. This solution is a dilute sulphuric acid, varying in strength from 1,200 to 1,400 Sp. G., according to the kind of cell and purpose for which same is employed. It is of the greatest importance that this "electrolyte" should be of the highest purity, and great care should be observed in introducing this into the battery, to prevent contamination of the solution by coming in contact with metallic or organic substances which would be dissolved by the acid.

It is of advantage to the user, where possible, to purchase from the manufacturer, acid already diluted to the required strength. There is always danger attendant upon the dilution of sulphuric acid in water, and considerable loss is apt to occur through the breaking of the container during the process of mixing the acid and water. "Electrolyte" is prepared by the manufacturers in quantity, in large tanks fitted with mechanical stirrers. This allows of a thorough admixture of these constituents of widely differing specific gravity and a constancy of composition of the resulting solution which would be difficult, if not impossible, to obtain were the mixture made with smaller portions.

Where, for any reason, it becomes necessary to prepare the "electrolyte" on the spot, pure brimstone sulphuric acid and pure distilled water only should be used, and every precaution observed in making the mixture*.

Brimstone sulphuric acid only should be used, because this acid is prepared direct from volcanic sulphur, which precludes the possibility of contamination with

arsenic, iron and the other metallic impurities common to acids produced as waste products of ores of iron and zinc. The so-called "pyrites acid" should never be tolerated, as the pyrites ore from which this is produced almost invariably carries traces of arsenic and kindred metallic impurities, which are ruinous to the plates if introduced into the "electrolyte" solution.

Pure distilled water is required,—not the condensations of engines or ice machines, as these may carry volatilized oil or traces of ammonia. If it is impossible to obtain distilled water, rain water is the best substitute. Ordinary hydrant water *should never be used*, because of the minerals and other impurities it contains. These impurities are dangerous, even in small quantities. We have seen valuable batteries ruined in a short time by metallic impurities introduced carelessly, as by diluting the solution or washing the elements with impure hydrant water, or by small particles of metal introduced into the solution by the use of a file on plate connections.

Where as much is at stake as a valuable set of plates, one cannot afford to be neglectful of such details as assuring the purity of the acid or "electrolyte" which goes into the battery, and employing scrupulous care and neatness of manipulation to prevent the smallest traces of injurious impurities coming in contact with the plates. The Franklin H. Kalbfleisch Company, 31-33-35 Burling Slip, New York City, were pioneers in the manufacture of pure acids and solutions for storage batteries. This company guarantees its "electrolyte" to be prepared only from pure Sicily brimstone acid and pure distilled water, and to be of full strength. Experience has shown that the use of such an "electrolyte" is absolute *insurance* against the many common battery troubles and assurance of long life of plates with full efficiency.

The Franklin H. Kalbfleisch Company has published several interesting and instructive pamphlets on the care and manipulation of storage batteries. These will be sent on application, free of charge, to parties interested in this subject.

FRANKE STUART HAVENS, PH. D.

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* The acid should be poured into the water, and never the water into the acid, as considerable heat is evolved by the chemical action of the union of acid and water. An explosion might result, scattering the strong acid about, if a little water were added to a larger amount of strong acid. Care should be taken to place the container where no damage will result if it is broken, as it often is, by the heat produced on mixing the acid and water